The JOURNAL
OF THE
FRANKLIN INSTITUTE
OF THE STATE OF PENNSYLVANIA
DEVOTED TO SCIENCE AND THE MECHANIC ARTS

VOL. CLXXI FEBRUARY, 1911 No. 2

SIMPLICITY IN THE MEASURES OF PHYSICAL QUANTITIES.

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COMPLAINT is frequently heard against the time robbing and inconsistent system of units of measurement which we have been so unfortunate as to inherit from our forefathers, yet in thus complaining about what our forefathers handed down to us, are we doing our best now to correct this state of affairs and not to pass on to our successors irrational, inconsistent, unnecessary, ill chosen and even incorrect units of measurement which are still under our control and are not yet so universally established and so deep rooted as the foot, pound, gallon, horsepower, etc.?

In the writer's opinion we are not doing all that can and should be done in this rapidly developing science of measures, with a view to the simplification of our every-day calculations and the rationalization of our systems of units of measurement. We are to-day doing things which are likely to take deep root and which our descendants would have quite as good a right to complain of as we have in complaining about the wretched system which has been handed down to us so firmly rooted that it will require generations to eradicate it.

The purpose of the present article is to point out what might be called the ideal system, from the stand-point of simplicity of calculations and clearness of conception, thereby showing the

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existing inconsistencies and mistakes, some of which it is well within our power to correct, but which if not checked will take deep root. It is not the intention to enlarge here upon the merits of the much discussed metric or the duodecimal systems. The universal adoption of the former is only a matter of time, although probably it will require a generation or two, and the adoption of the latter is beyond our hopes and will probably be done first by those nations like Japan and China, which are younger in this branch of civilization and can therefore adopt radically new departures with less mental inertia.

In order to see whether we are to-day doing anything which might just as well be done better and is capable of being changed, let us first examine what might be called the theory of systems of units.

Measures are intended for designating definite amounts of something. With but few exceptions these things are all physical quantities, like length, weight, time, velocity, angles, electricity, light, heat, power, etc. These physical quantities are all given to us by nature and are not creations of man; we therefore have no choice but to accept them as we find them. But in no case does nature give us any units in terms of which these quantities are to be measured; these units are always the creation of man and are therefore within our power to designate. In some cases nature has indicated to us a rational unit, as for instance the period of the revolution of the earth, on which we have based our indestructible and reproducable unit of time; but with few exceptions, the many units that we have are entirely artificial creations, although a creditable but futile attempt was made to base the metric system on a natural basis.

To measure a physical quantity, it is necessary to propose, define and adopt some one fixed amount of it, which is to be considered as the unit of that quantity; without some form of unit it is evidently not possible to express or measure an amount of that thing. Moreover, if this thing is a physical quantity which is used and measured frequently, it is very desirable to give that unit a name, like the foot, horsepower, candlepower, volt, etc. When the unit is unnamed one has a natural hesitancy to use it, and it then becomes necessary to carefully and clearly define it, whenever it is to be used to measure a quantity; and if in such a case a physicist omits to state the units in terms of

which the quantities in his laboriously deduced and valuable physical relations and formulas are expressed (which unfortunately happens not infrequently), then his results can be used only to show relations but not numerical amounts, and they therefore lose much of their practical value.

In the ideal, most rational, and most simple system of measures and units, the first thing to do is to find out what the true nature of each of the physical quantities to be measured is, then to select some one definite amount of each, as the unit in terms of which other amounts are to be measured, and preferably to choose these units so that the relations between them will if possible be unity. This is the way it is done in that most rational of all systems, the c.g.s. system, which has been of such inestimable value to the physicist and on which our ideally simple system of electrical units is based.

This has unfortunately not always been done in the past, as for instance in the case of horsepower and watts, gallons and cubic feet, or joules, calories and foot-pounds, etc., and the result is that there exist to-day numerous cases in which there are several units for measuring the same physical quantity, where one would suffice. This not only has caused unnecessary complication and requires troublesome numerical conversion factors for reducing one to the other, but it tends also to give the impression that there is a real physical difference between the quantities measured by the different units, when as a fact they are identical.

This has been one of the chief causes of the existing complication in our systems of measures and units. In some cases, as for instance in horsepowers and watts, it was due to a natural development and was not done without good reasons; the horsepower was used as a unit long before the watt was thought of; and the watt is a necessary consequence of the simple system of electrical units. In such cases the only thing to do at present is to use the more rational one, the watt or kilowatt, more and more to the exclusion of the horsepowers, as is being done, and in course of time the irrational one will become obsolete. It is quite as simple for the mechanical engineer to multiply his foot-pounds per second by 1.356 to reduce them to watts, as it is to divide his foot-pounds per minute by 33,000 to reduce them to horsepowers.

In other cases, however, in which the irrational unit has not yet become as deeply rooted as the horsepower, the change to the more rational one could be easily accomplished by concerted action among those who have sufficient regard for the coming generations to set an example by adopting and using it. The fittest will always survive in the end, according to natures' laws, but nature can be aided in her necessarily slow methods.

A good illustration of this natural tendency to simplification, and of the mistake made in specifying and naming unnecessary units, is given by the history of the original metric system. The originators specified five units, the gramme, metre, litre, are and stere, for the physical quantities weight, length, capacity, surface, and volume respectively, when two, namely weight and length, are in fact all that are necessary. Hence the original system was unnecessarily complicated and it was no doubt in part due to this unfortunate complication that its universal adoption was not as rapid as it should have been. Had it been shown originally that all the several dozen awkwardly related units, which we inherited mostly from England, could be replaced by only two, and that these two can even be made to bear a very simple relation to each other,—the adoption of the metric units and the abandonment of our wretched system, would no doubt have been very greatly facilitated.

That some of these five metric units were unnecessary is shown best by the fact that by nature's tendency to simplification two of them, the are (surface) and the stere (volume), have nearly gone out of use already, being replaced by the metre, or its multiples. Small surfaces are to-day invariably given in square centimetres, decimetres or metres, and large ones like those in land measures, are given in square kilometres; while small volumes are given in cubic centimetres or decimetres, and large ones in cubic metres. The natural tendency to simplicity has therefore already corrected in part the mistakes made by the originators, by practically eliminating two of these unnecessary units.

The third one, the litre, is still in use, although it too is quite unnecessary, because it is a volume, and its equivalent, the cubic decimetre, would therefore suffice; this would have simplified the system, and would have avoided the present unfortunate discrepancy in the metric system in that the litre, which is legally

defined as the volume of a kilogramme of water, differs slightly from a cubic decimetre.[1]

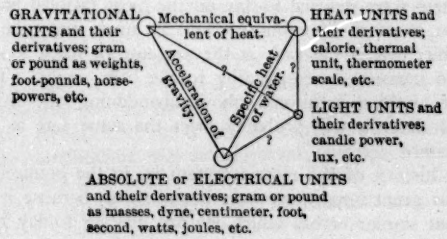
The tendency to abandon this unnecessary litre, like the are and stere, is shown by the fact that chemists to-day usually specify volumes of liquids in cubic centimetres, and water in tanks and large reservoirs is often measured in cubic metres instead of litres. To measure wine, milk, etc., in cubic decimetres, instead of litres, would at first be opposed by prejudice and mental inertia, but it will probably not be denied that if a new system were devised to-day on the most rational basis possible, the measure of volume would be made the cube of the linear unit; this is the case in the absolute or c.g.s. system, in which no measure corresponding to the litre, exists. There is therefore nothing irrational about abandoning the litre, and sooner or later it will probably meet the same fate as the are and the stere.

This history of the metric system is, in the opinion of the writer, of great importance as a lesson to us, because it clearly points out similar errors which we are making to-day in other systems of units which are not yet so deeply rooted in practice that they could not be corrected now, thereby saving us, and the following generation, entirely unnecessary complications. Such mistakes will in the future no doubt be corrected by the natural tendency to simplicity, just as was the case with the metric system; hence there seems to be no reason why we should not enjoy the benefit of this simplicity at the present time, and also save ourselves from the inevitable censure of coming generations which would be quite as just and even more so, as our censure of the past generations for the unnecessarily complicated system which they have passed on to us.

Before specifying some of these unnecessary complications, it will facilitate matters to analyze briefly the general relationship of our measures. Omitting for the present the photometric units based on the candle, it will be found that all our units can be divided into three distinct groups, to one of which every unit belongs. This may be shown diagrammatically in the adjoining figure taken from the writer's "Conversion Tables" (p. 3).

[1] Conversion Tables, Hering, p. 45.

These three groups are shown by circles at the three corners of a triangle. The first and most important one, from the standpoint of the basis of a rational system, is the lower one. This is the group of absolute units. They are called so because they are the same throughout the universe, are invariable, and are independent of any constant of nature.[2] This group includes all the electrical and magnetic units, which were very fortunately and wisely based on the fundamental absolute units and are


GRAVITATIONAL UNITS and their derivatives; gram or pound as weights, foot-pounds, horse-powers, etc.
Mechanical equivalent of heat.
HEAT UNITS and their derivatives; calorie, thermal unit, thermometer scale, etc.
Acceleration of gravity.
?
Specific heat of water.
?
LIGHT UNITS and their derivatives; candle power, lux, etc.
?
ABSOLUTE or ELECTRICAL UNITS and their derivatives; gram or pound as masses, dyne, centimeter, foot, second, watts, joules, etc.

therefore fixed and invariable and are independent of any constant of nature.[3] They also include the gramme or pound considered as mass as distinguished from weight, the dyne, erg, centimetre, foot, second, etc. All these units, being invariable, and being independent of the determination of any constant of

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[2] Exception might be taken to saying that our unit of time is independent of a constant of nature, because it is based on the revolution of the earth around the sun; but unlike the mechanical equivalent of heat, the specific heat of water, the acceleration of gravity, etc., that constant of nature has been determined with very great accuracy and may therefore safely be assumed to be known absolutely. But whatever that constant of nature may be, the second of time is at least a unit which is invariable throughout the universe. Time is, by general agreement, accepted as one of the three fundamental absolute units in the c.g.s. system.

[3] Exception might be taken to this on the ground that the specific inductive capacity and the permeability of air are involved in some of them; hence some of them might be different elsewhere in the universe. But their relations are at least definitely known, without having first to determine those constants of nature. Moreover, these two constants of air are apparently so little different from those of a vacuum that no appreciable error is made by neglecting the difference.

nature, form the best group and the one on which all other units should be based as far as practicable.

The second most important group is that of the gravitational units. These all involve the constant of nature called the attraction of gravitation of our earth; they are therefore purely terrestrial units and would be different on other planets. They are in fact slightly different even on different parts of the earth. They include such units as the gramme or pound considered as weights, hence the horsepower, the foot-pound, etc. Their values depend upon the constant of nature called the acceleration of gravity; hence they are known only to the same accuracy as that constant is known. It can be shown that this constant is the connecting link between this and the first group (the absolue units); hence knowing this constant, the absolute values of all the units of this group can be established. Had our forefathers based the gramme or the pound as weights, on a more rational basis than the attraction of our own earth, as was subsequently done in the establishment of the units of force called the dyne and the poundal, our system of measures would have been relieved of this whole group, hence simplified by 33⅓ per cent.

The third group is that of the thermal units. It embraces such units as the calorie, the British thermal unit, the thermometer scales, etc. They have been based on a property of water; hence for determining their value, this constant of nature must be known; and the accuracy of the units is no greater than that of our knowledge of that constant. It can be shown that the connecting link between this group and the first one (absolute units) is the constant of nature called the specific heat of water in absolute measure. Hence knowing this constant, the absolute values of the calorie, the British thermal unit, etc., can be established from the absolute units. Had our forefathers based the calorie or the British thermal unit on a more rational basis than a property of water, as was subsequently done in the establishment of the unit of energy (therefore including heat) called the erg or the joule, our system of measures would have been relieved of this whole group, hence simplified by 33⅓ per cent. In an entirely new system of units there seems to be no reason why both of these groups should not be eliminated, thus simplifying our systems by 66⅔ per cent. This is done in the c.g.s. system of units which is a specific set of absolute units.

The two constants of nature mentioned above are moreover the only ones necessary for connecting the units of these three groups with each other, that is, for converting quantities in terms of one unit, into their equivalents in terms of another. As these two constants rigidly connect these two groups with the first one, the two former must thereby be rigidly connected with each other. This connecting link between the second and third groups is another constant of nature called the mechanical equivalent of heat. The latter is equal to the specific heat of water divided by the acceleration of gravity.

The light units have in this diagram (p. 134) been shown as a fourth group. They were originally based by our forefathers on the arbitrary "candlepower" which has no known relations to any of the other groups of units, hence they form a group separate and distinct from all the others. It is unfortunately not possible with our present knowledge to convert a unit of light flux (a lumen) into watts, calories per second, or horsepowers, as neither of these three connecting links is known. The determination of any one of the three would establish the other two. This would mean the determination of the electrical, thermal or mechanical equivalent of light. If light is considered a physiological phenomenon, there might be difficulty in establishing such an equivalent; but by defining the unit of light flux in terms of some fixed wave-length, it seems that such an equivalent could be determined; light of other wave-lengths would then have to be referred to this one by means of factors.

The group of light units affords a good illustration of a case in which it is still within our power to simplify the system of units, as was suggested by the writer when this diagram was published seven years ago; the light units are not yet in such extended use that it would be useless to try to introduce a better system.

If instead of defining arbitrarily some unit of light and afterwards finding its connecting link with the other group of units (as was done with the other two groups), the unit of light be originally defined in terms of the absolute system (as was done with the electrical units), and its light value determined afterwards (as was done in the case of the ohm and the ampere), then this group would come under the group of absolute units.

An ingenious method of doing this was suggested by Dr. C. P. Steinmetz several years ago.[4] He there proposed to make the unit of light flux equal to one watt by definition, and then to determine the light produced when all of this power was converted into light. As the watt is an absolute unit, this would bring the light units into the group of absolute units.

The above analysis in connection with that diagram show the nature of some of the possible simplifications of our system of units, and the unwise methods that have been used in the past. It teaches us what to avoid at the present and in the future. While we cannot expect to correct these unfortunate errors of the past by any sudden revolution in our system of units, yet it is within our power to favor the simpler system by using it in preference to the older, more complicated one whenever practicable; the advantages would then be appreciated and the example would be likely to be followed by others.

As an illustration, calculations concerning electric furnaces involve quantities of heat. If the unit of heat is taken as the joule, instead of the calorie or the British thermal unit, and that of the flow and of the rate of producton of heat is taken as the watt instead of the calorie per second, both of which of course would be quite correct,—it at once brings the thermal units into the group of absolute units and thereby avoids using the troublesome numerical conversion factor which connects these two groups. The relations between the units then becomes unity, as it is in the system of electric units, and all calculations are thereby very greatly simplified. In calculations involving only heat and chemical energy, the calorie and British thermal unit are to-day the simplest ones to use, because the tabular data are at present generally given in terms of them, but there seems to be no good reason why such data should not also be given in joules. It is not recommended here to make all calculations in the absolute units, but merely to do so by preference when there is a choice; in this way we may hope that at some future time this ideally simple system will come into general use.

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[4] "Primary Standard of Light," Trans. Amer. Inst. Elec. Eng., 1908, vol. xxvii, part 2, p. 1319. See also deduction from it in article "On the Relations of the Measures of Light and Power," Hering, Elec. World, Sept. 19, 1908, p. 621.

The above has shown how certain complications may be avoided by not establishing new groups of units on different bases, connected together by incommensurate constants of nature, as was formerly done.

Another simplification, and an important one which might often be made use of to-day, is to adopt only one unit for each physical quantity. Exceptions may and unquestionably are justified when, to eliminate the troublesome factor π, two units are adopted for the same physical quantity, as for instance in the square mil and the circular mil, the degree and the radian, the gilbert and the ampere-turn, the lumen and the spherical-candle, etc., as will be discussed later. It is also understood here that such decimal multiples as kilometre, centimetre, etc., are considered as one unit, the metre; and that the erg and joule are the same unit, as the latter is just ten million times the former.

The simplest illustration of the above is that we should adopt some one unit of length, like the metre, and drop all others like the inch, foot, yard, mile, etc. But in these common units this is already well understood and needs no further mention here. It is, however, not so evident in the less common units and it is with some of these that important simplification becomes possible, and would be easier to introduce than changes in such deep rooted units as the inch, pound, etc. Among these may be mentioned the following:

Energy is the same physical quantity whether it appears as mechanical, thermal, luminous, electrical, magnetic, chemical, or acoustic energy; hence in all of its forms it could be measured in terms of one unit and in fact is so measured in the absolute system by the erg. Instead of this one unit we now use the foot-pound or kilogramme-metre, the British thermal unit or calorie, the lumen or spherical-candle, the joule, etc. To some extent the use of some of these may still be justified because it would involve a too radical (though still very desirable) change to be practicable as long as we adhere to the older systems. But in some respects it would be quite possible and not at all impracticable to make changes in this direction now. The heat units, for instance, might well be abandoned entirely and replaced by the larger absolute unit, the joule, which may be said to be the same unit as the erg. This would merely require the tabulated values, such as those of specific heats, latent heats, chemical

energy, etc., to be recalculated once for all, after which all electro-thermal calculations would be reduced to the ideal simplicity of the other electrical calculations, and the specific heat of water (in absolute measures), besides both the electrical and the mechanical equivalent of heat, would be eliminated from all such calculations; the relations between electrical and thermal energy would then all become unit relations, which is the ideal. This would be of great value in electric furnace calculations.

If furthermore the suggestion of Dr. Steinmetz above referred to were introduced, all calculations connecting light energy with electrical energy would be reduced to the same ideal simplicity of unit relations.

If finally weights when considered as forces (as they always are in all calculations of mechanical energy) were expressed and measured in absolute units of force, such as the dyne, or its multiple the megadyne, then this group of calculations would also be reduced to the ideal simplicity of unit relations, as a dyne acting through a centimetre generates one erg of heat energy. The group of gravitational units would then be brought into that of the absolute units.

Although some of these changes would be too radical to be introduced at once, yet if it be recognized and remembered that this is the proper direction of development toward very desirable simplicity, and if the leaders in their respective professions would adopt and gradually introduce the changes in these directions and teach them to their students, the reform would unquestionably be ultimately adopted, in the same way as the metric system is slowly but surely becoming more commonly used, understood and adopted. It may take generations, but in the opinion of the writer these changes are bound to come.

The same that was said about energy applies to power also, that is, to the time rate of energy. As a physical quantity, any flow or transmission of heat or of energy of any other kind, be it by conduction, convection or radiation, is power, because it is a time rate of energy, and hence is correctly measurable in ergs per second, which is merely a decimal subdivision of the watt (ten million ergs per second) or the kilowatt. Many of the calculations for electrical furnaces are reduced to ideal simplicity by representing all heat flows or streams or currents of heat, such as the heat leakage through the walls, the electrodes,

or directly by radiation, in watts instead of calories per second (or worse yet, British thermal units per second). Such flows then become directly comparable with the input of power which is always represented in watts. The complete abolition of the calorie and the thermal unit, in electrical furnace calculations, would be a simple matter; it is a good illustration of what could be done to-day very easily toward this very desirable simplification.

In this connection attention may be called to an error not infrequently made by some writers who have used the "calorie per second" as the unit of heat flow and called it the c.g.s. unit. A heat flow is physically the same as power, and the c.g.s. unit of power is the erg per second and not the calorie per second. This is another instance of departing from, instead of leading to, the ideally simplest system.

Light radiation or luminous flux is physically also exactly the same kind of a quantity as mechanical power, and with properly chosen units could also be measured in absolute power units, ergs per second or watts. Now such radiations are measured in lumens or spherical-candles, but if this unit of light flux had originally been made a watt or some decimal of it, all such calculations concerning luminous power would have been reduced to the ideal of simplicity of unit relations. Here, however, the numerical equivalency,—which, analogously to the term mechanical equivalent of heat, would be called the electrical equivalent of light,—is still unknown, and until it becomes known the light units and calculations cannot be reduced to this ideal simplicity. If the plan of Dr. Steinmetz referred to above were carried out, namely, to make the unit of light flux equal to one watt, by definition, and then determine the candlepower value from this, as was done with the electrical units, the reduction to unit relations would be complete. Until then we must continue to express this relation in terms of the ratio of lumens to watts.

Electric power is always expressed in watts, and hence calculations concerning it have already been reduced to ideal simplicity. The same is true of magnetic power, such as is transmitted from the primary to the secondary of a transformer. Mechanical power is still expressed in horsepowers, but a change to kilowatts has already begun when such power is to be converted into electric power. Lastly, chemical power, that is, the rate at which chemical energy is set free or consumed, as for

instance in combustion, explosion, chemical changes in furnaces, or if purely physical as in refrigeration, could quite as well be to-day expressed in watts instead of calories per second, thereby bringing all these calculations into the group of simple unit relation units.

Besides these cases of energy and power units, there are numerous others in which we are now using two or more units when one would suffice, thereby not only complicating calculations but actually often giving the impression to the student that the quantities are different physically when as a matter of fact they are exactly the same.

Striking examples of this are found in the photometric units. When light issues from a surface, for instance, it is exactly the same physical quantity, namely light flux, whether it issues by reflection, as from a white wall, or by transmission, as through ground glass, or by generation, as from the surface of a source; furthermore, it is exactly the same physical quantity, before it reaches a reflecting surface as it is after reflection. Yet notwithstanding this absolute physical identity, it was proposed and recommended, even quite recently, to measure the density of this same flux by three different units, defined by different derivational formulas. This, in the opinion of the writer, is a decided retrograde step and one which could be and should be changed before it has become so generally adopted as to become difficult to eradicate. This is one of the cases which it is the purpose of this article to call especial attention to, as an illustration of how we are at the present time actually creating entirely unnecessary complications not only for ourselves but also for future generations, when it is entirely within our power to take an important step now toward simplification and rationalism, which will be bound to come later. It can be shown [5] that the complicated system of a multiplicity of different photometric quantities and units which it has recently again been proposed to adopt, really consists of a simple system of only three physically different quantities, namely flux, flux density and flux $\times$ time; in an ideal system they would be measured in watts, watts per sq. cm., and joules or ergs, respectively, or their decimal derivatives or multiples.

[5] "Calculating and Comparing Lights from Various Sources," Trans. Illum. Eng. Soc., Nov., 1908, vol. iii, p. 645.

It is presumably not disputed that in all four of the above-mentioned cases of light from a surface, the radiant energy is light flux. Then why should its density or intensity be named and measured by such entirely different names and units as "illumination," measured in metre-candles when it impinges on the surface; "radiation," measured in lumens per square metres after it is reflected by the surface; "brightness," measured in candles per square centimetre when it originates at the surface; and by several of these indiscriminately (apparently left to one's taste) when it originates behind this surface? Yet this is what has recently been recommended and endorsed.

Physically all these are true flux densities and therefore are all in fact the same physical quantity, hence measurable in the same unit, namely flux divided by the space in which it is confined; and when so measured, the relations between them at once become the simplest possible; while if not so expressed and measured their identity is not evident; on the contrary, the very fact that they are expressed by different names and units and even by different derivational formulas, naturally gives the impression that they are different physical quantities.

One of these units, namely brightness, measured in candles per sq. cm., is even worse than an unnecessary complication, as it is physically or mathematically a hybrid or inconsistency. Candlepower is distinctively a point conception, and a true point cannot have any dimensions; hence to speak of candles per area is giving a point dimension, which is a mathematical absurdity. Brightness when so defined will be found to be a quantity which is incommensurate with all the others, hence is not interconvertible with the others. Moreover, candlepower is itself a flux density, hence "candles per square centimetre" represents a density of a density, which is a physical absurdity.

When correctly analyzed it will be found that this physical quantity, brightness, is in fact a true flux density and nothing more, and is therefore measurable in exactly the same units as illumination, or as radiation from a surface. This has been discussed more fully elsewhere by the writer.[6]

It is admitted that for convenience in calculations, luminous

[6] "Simplifying Some of the Calculations of Light," Elec. World, Sept. 26, 1908, p. 673.

flux density may be expressed and measured in terms of two different units, as will be further discussed below. The point emphasized here is that a number of ostensibly different physical quantities are in fact identical and it would simplify matters so to recognize them.

The ideal unit for all of these flux densities and the one giving unit relations with others, would be the erg per second per square centimetre, or watt per square centimetre, in terms of which the density or intensity of all transmissions of energy are measurable, whether by a belt, a current-carrying wire, magnetic flux in a transformer, heat or light flow in a body or by radiation from it, electromagnetic waves in wireless telegraphy, etc.

In connection with the flow of heat, no units for measuring thermal resistance and conductance have as yet been generally adopted, and it is therefore still within our power to establish rational ones which have unit relations, at least with the electrical quantities. A thermal resistance can be shown to be physically equal to degrees of temperature divided by watts, and a thermal conductance to watts divided by degrees. It has been proposed to call the unit based on the former a thermal ohm, and on the latter a thermal "mho," on account of their analogy to the electrical quantities. With those units, calculations of heat flows are reduced to the simplest possible, that is, to unit relations, at least when the energy is expressed in electrical units as it is in all electrical furnaces. This has been discussed and illustrated elsewhere more in detail by the writer.[7]

In still another instance entirely wrong units have been used to measure quantities, and it resulted in leading to entirely erroneous conclusions. It was required to express and measure those physical properties of a material which determined its suitability for use as electrodes of electric furnaces. Formerly it was thought that a material was better for this purpose in proportion as its thermal conductivity was lower; also in proportion as its electrical resistivity was lower; therefore measuring that quality in terms of those units. But it has recently been shown[8] that this was not correct, and that it leads to entirely

[7] "Thermal Resistance and Conductance; the Thermal Ohm and Thermal Mho," Metal. and Chem. Eng., Jan., 1911, p. 13

[8] "Laws of Electrode Losses in Electric Furnaces." Trans. Am. Electrochem. Soc., 1909, vol. xvi, p. 265.

erroneous conclusions. It was shown that the correct units are two entirely different ones. The correct one for measuring that physical quality of an electrode material which determines the loss of energy in it (when operating under the ideal conditions) is proportional to the square root of the ratio of the thermal to the electrical conductivity; while the correct unit for measuring that quality which determines its size is proportional to the square root of the reciprocal of the product of the two conductivities. Hence neither conductivity alone is any criterion, it is the square root of their quotient and of their product which governs the results.

This is cited here merely to show the grave errors which can arise when in the more complicated cases sufficient care is not taken in the proper selection of the correct units; also as another instance in which the choice of new units gives us an opportunity to select those which will reduce calculations to the simplest possible, namely to those in which there are unit relations, as the thermal conductivities can in this case be to great advantage represented in terms of the electrical units, watts.

When there is any doubt as to the true physical nature of a quantity it may generally best be determined by deducing its so-called "dimensions"[9] which will at once show it. Great care must, however, be taken, as errors are easily made resulting in absurdities due to the neglect of quantities whose numerical values are unity in a formula, or to the neglect of the so-called "suppressed quantities," or sometimes to the unfortunate inconsistency that the dimension of an angle in this system is unity and therefore is not noticed.

In general therefore, as has been shown above, it will greatly simplify our measures, and should therefore be very desirable, to select one and only one amount of each physical quantity as the unit for measuring it. There are, however, important justifiable exceptions. Units are not only for expressing amounts of physical quantities, but also for making computations in which those amounts are involved. Hence an important feature in the selection of a unit for an ideally perfect and simple system is to make it as convenient a one as possible for calculations. In some

[9] For a tabulated list of such dimensional formulas classified according to their dimensions, see this Journal, Sept., 1910, p. 194.

cases it is therefore very desirable to have two numerically different units for the same quantity, they being so chosen that each is the simplest possible one for each one of two groups of calculation.

The chief reason for this is the fact that the ratio of the diameter to the circumference and area of a circle or of a sphere, are incommensurate, and that calculations from one to the other involve this factor π in various forms. It is of course impossible to eliminate this constant of nature entirely, but it is quite possible to eliminate it from a very large number of calculations by using two units differing from each other by this factor in its various forms, so as to enable us to use either one or the other, whichever involves the least calculations.

A good illustration is the square inch and the circular inch; both are units of area; the latter is the most convenient to use for circular areas and the former for all others. In circular pipes, for instance, the area of cross section in terms of circular inches is equal simply to the square of the diameter, thus eliminating π from all that very large group of calculations.

Another such justifiable case of double units is the gilbert and the ampere-turn, for measuring the magnetomotive force. The gilbert is the absolute unit, hence the more rational one for an interconnected system of units having unit relations; but the ampere-turn is generally the simplest one to use because it eliminates the troublesome factor π from a relatively very large group of such calculations. A gilbert is equal to $10/4\ \pi$ ampere-turns.

Another instance is the radian and the whole circle, for measuring arcs or angles. Sometimes the one and sometimes the other is the simplest to use. They too differ by π, a complete circle being equal to $2\ \pi$ radians. The degree has not been included here as an angular unit, as it is irrational and avoidable, and should have been some exact decimal subdivision of a whole circle, as for instance $^1/_{100}$ or $^1/_{1000}$.

Another good illustration of the great value of double units to eliminate π from calculations, are the two units of light flux, the spherical-candle and the lumen. Both are true and correct units of flux, being both rates of propagation of luminous energy, or physically the same as power, hence also measurable in watts

or ergs per second. Again they differ by the factor π, a spherical-candle being equal to 4π lumens. Either can be used in calculations, whichever reduces the computations to the simplest possible. If only one were used, it necessarily follows that many of the calculations would involve multiplying or dividing by 4π, when this additional calculation might just as well have been dispensed with, just as in the use of circular mils for square mils in calculations involving the cross section of round wires. In the case of the spherical-candle the unit of the solid angle used is the whole sphere, just as in angular revolutions per minute the complete circle is used as the unit of plane angles. While in the case of the lumen, the unit of solid angle used is the absolute one, namely, a certain fraction of a whole sphere equal to $1 \div 4\pi$.

This is a good illustration of a case in which a reform tending to simplicity of calculations might be introduced at once, without disarranging any long-established system. Many calculations are to-day made in terms of the unit lumen, which would be greatly simplified by using the other and more suitable unit, the spherical-candle.

Another important case of justifiable double units is that of luminous flux density. At times (when the light issues from a point) it saves calculation to express this density in terms of a solid angle, hence the unit of density or intensity called the candlepower. At other times (when the flux impinges upon, passes through, or issues from a surface), it is more convenient to express this density in terms of a flat surface, hence the unit foot-candle, called illumination. Both are very useful and we could not do well without either.

Another illustration of a double unit is the coulomb and the ampere-hour (the latter equals 3600 coulombs). This, however, differs from the others in that it would be within our power to simplify it by simply making the units of time decimal multiples of each other. Hence this double unit is justified only because we have to use an irrational set of units of time.

In conclusion a few words may be said about the naming of units. An unnamed unit is like an unnamed tool, it cannot be referred to or specified clearly and definitely, and when the units in terms of which any results or formulas are given are not

understood beyond doubt, the usefulness of such results generally suffers greatly if in fact it is not entirely destroyed.

In general it seems very much better, in view of the large number of names which one has to learn, to make the name of a unit self explanatory, whenever the nature of the unit permits it, and when the name does not become too long. For instance, "foot-pounds," "miles per hour," "pounds per square inch," "r.p.m." standing for "revolutions per minute," "atmosphere" (pressure), "B.T.U." standing for "British thermal unit," "steradian" standing for solid radian, etc. In all such compound names the universal custom is that a hyphen means the product of two units, while the word "per" means the quotient of the first divided by the second. In all such cases no explanation of the units is necessary; and it is not necessary to look them up in reference books. Units so named adapt themselves automatically to the metric and the English system. Hence specific names in such cases are unnecessary and generally inadvisable; and when they are given it is likely that they will never be universally adopted; the name "barie" for pressure, "kine" for velocity, are good illustrations of unnecessary names.

There are some cases, however, in which such compound names would be more likely to confuse than to be self-explanatory, and it is then preferable to give them a specific name. An electric current, for instance, is the ratio of the electromotive force to the resistance, hence if only the two latter were named, the unit of current would be called "volts per ohm"; this is not only confusing but does not in itself suggest a current.

When a unit is used very frequently, like the three chief electrical units, a specific name is decidedly preferable, even though the act of learning them the first time may give a little trouble. It is when such specific names become very numerous that they may be justly objected to.

Custom may often be relied upon to decide whether a specific name is advisable or not. The unit of magnetic flux, for instance, has been given the name of maxwell, but this has not replaced entirely its former self-explanatory though longer name "line of force." Naming units after distinguished pioneers, as was done in the case of the electrical and the magnetic units, seems to be a commendable custom provided it is not carried too far.

When analytical investigations are made without reference to any specific units, it is usual to claim in a general way that the "absolute" or the "c.g.s." units are understood. This is generally safe because the relations in that system are usually unit relations, and whatever may be the physical quantity (even if its nature is unknown) there generally must be some one and only one unit in that system, for measuring that quantity. This has become a habit and as such has led to carelessness, as in the case above cited in which "calories per second" were incorrectly termed the c.g.s. unit, when the latter really is the "erg per second."

As many of the c.g.s. units have no names and as it is often very convenient to refer to them by name, the commendable suggestion was made some years ago by Dr. A. E. Kennelly, to designate them by prefixing "ab" or "abs" to the name of the carresponding practical or working unit, as for instance abvolt, absohm, etc., when referring to the electromagnetic system, and "absta" or "abstat" when referring to the electrostatic system.

In a subsequent article the writer intends to show by specific illustrations how by only slight modifications in our present system of units a very great step could be taken toward this ideal system in which calculations are reduced to the simplest possible by the reduction of all relations to unity or to powers of 10, like in the system of electrical units.

Summary.—In the above the writer has endeavored to show by an analysis of our systems of measures and units, that many of the numerous every-day calculations of the engineer, which must be made with such units, could have been greatly simplified and their clear understanding facilitated and enhanced, had the systems by which some of these units were originally designated been more rational and consistent ones. While it is admitted that it might be too revolutionary to change our present irrational system to the rational one by a complete and radical transformation, yet this very desirable change, which is bound to come in time, could be greatly encouraged and accelerated by continually keeping the ideal system before us in our minds, teaching it to students, and approaching it at every possible occasion by small but positive and decided steps in the right direction, and by all means not making existing matters worse by taking

any steps in the wrong direction, away from this path to the ideal. A close approximation to this ideal system is already in extended use among physicists under the name of c.g.s. system, and there appears to be no reason why engineers, who apply physical laws to practical problems of construction, should not also enjoy the advantages of similar simplicity in their practical work.

Iron Ore Resources of the World. L. DE LAUNAY. (*Iron Age*, lxxxvi, 12.)—An article worthy of close consideration by iron producers and users. M. de Launay refers also to probable new iron ore development, after the reserves now in sight are largely exhausted. Northern Sweden contains large quantities of rich iron ores of more than 60 per cent. Recently iron ores have been discovered in the Lake Superior region, known to contain 2,000,000,000 tons of metallic iron, with a possible 36,000,000,000 tons. When Canada is explored, no doubt important discoveries will be made there. Newfoundland appears to have almost 2,000,000,000 tons of iron ore containing 65 per cent.; and similar ores are abundant in the Adirondacks. In the Southern Hemisphere, Minas Geraes is to be taken into account. For lower grades of ore, France may take the most prominent position with its supplies in Lorraine, Normandy and Algeria; followed by Germany with its ores found in German Lorraine.

The Mechanigraph. (*Iron Age*, lxxxvi, 13.)—This machine renders an opaque pencil or pen drawing transparent and printable practically instantaneously, at a cost of approximately one-third of a cent. per square yard. The drawing to be treated is passed through the first pair of rolls which carry it through the bath containing the transparantor liquid, and from there along the moving tapes to the drying rollers, which are warmed by a current regulated by the rheostat beneath. The pressure on the drying rolls is maintained by adjustable, spherical iron weights.

Hypochlorite Treatment of Water Supplies. GEO. A. JOHNSON. (*Eng. Record*, lxii, 12.)—In view of the belief gradually gaining ground that mere filtration through sand is by no means a certain arrester of bacteria, and thus is unreliable as a water purifier, the above paper on the use of hypochlorites as a germicide is of interest. Mr. Johnson summarizes the advantages of the process thus:

1. Substantially complete destruction of objectionable bacteria particularly those of intestinal origin.

2. Reliability and ease of application of the chemical and small variation of required dose.

3. Absence of poisonous features, either in the chemical or in its resultant decomposition products.

4. Nominal cost both of chemical and its application.

5. Speed of reaction, requiring no substantial basins other than storage facilities.

6. Saving in cost of coagulation of waters requiring clarification or filtration.

7. Permitting a very high rate of filtration, with high bacterial efficiency.

8. Reduces clogging of filter beds, and lengthens runs between cleanings, by destroying various forms of algæ.

Its limitations are: Inability to remove or destroy (1) all of the spore forming bacteria (these are not considered pathogenic to man), (2) bacteria imbedded in suspended water, (3) inability to remove turbidity or (4) appreciable amounts of color, or (5) organic matter, or (6) swampy tastes or odors, or (7) creosote tastes or odors, and (8) inability to soften water, and (9) difficulty of application to waters containing reducing agents.

Blistering of Sterling Silver during Annealing. ANON. (*Brass World*, vi, 349.)—It is possible to produce blisters on perfect sterling silver by overheating it during annealing in an oxidizing atmosphere. It is generally assumed that the blisters are the fault of the metal itself, and are caused by careless or imperfect melting; this is asserted to be radically wrong. Experiments show that sterling silver cannot be blistered when a reducing flame is used for annealing, but an oxidizing flame produces numerous blisters. The theory is advanced that silver absorbs oxygen energetically when the temperature approaches the melting point.

Slow Rusting Iron Produced in the Open-hearth Furnace. ANON. (*Eng. News*, lxiii, 6.)—"American ingot iron" has recently been placed on the market by the American Rolling Mill Co., which exhibits a high resistance to corrosion and is therefore valuable as a structural material. Although produced by the basic open-hearth process it is closely similar to wrought iron. It differs from steel in that its contents of carbon, manganese, and silicon are only fractions of the amounts in ordinary soft steel. In appearance, strength, and ductility this is practically identical with wrought iron. The usual ferromanganese recarburizer is omitted and ferrosilicon, or an equivalent, is used to purify the bath of its oxides. Aluminum is added in the ladle to carry off the gases dissolved in the fluid metal. Relative corrosion resistance tests with sulphuric acid show that ingot iron has 40 to 60 times the resistance of steel, and 20 to 40 times the resistance of wrought iron.

THE COPPER DEPOSITS OF FRANKLIN-ADAMS COUNTIES, PENNSYLVANIA.

BY

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(*Presented at the meeting of the Mining and Metallurgical Section, Thursday, May 19, 1910.*)

THE existence of copper ores in the South Mountain range of south-central Pennsylvania and northern Maryland has long been recognized. The numerous abandoned workings to be seen throughout the region indicate that considerable amounts of money have been wasted in vain attempts to win the metal, and it may well be doubted whether deposits of sufficient magnitude to repay operation can have escaped discovery. Nevertheless the renewed activity in prospecting exhibited during the past few years has attracted considerable attention to the district, and the results of a hasty examination made during October, 1909, seem accordingly worth placing on record.

HISTORY.

The presence of valuable metals in the region was noted as early as 1787 by the German traveller Schöpf, who in his description of the American Colonies [1] stated that "The South Mountain in its entire extent contains rich crevices, gangues, and nests of ore, especially of iron and copper." It is said that mining was begun about 1810, and in his report of 1858 Henry D. Rogers [2] described the results as follows: "Near Miney Run search was made many years ago for copper ore, but nothing was found to justify the expectation of finding a productive vein of that mineral. A small quantity of copper ore was once obtained, and a furnace built for smelting it, in a small ridge north of Jack's Mountain, but the exploration was abandoned. The metal occurs in the form of a green and blue carbonate, with a little native copper. Evidently the ore is not abundant."

The next thirty years witnessed repeated attempts at mining

at various points, but so far as recorded in the scattered publications on the subject listed in the bibliography none of them repaid in any degree the cost of development. In 1892, when a detailed geological examination of the region was made by Miss Bascom,[3] all were abandoned, but since that time there has been a revival of interest, and at present operations are being carried on in several localities, although the results are as yet not particularly encouraging.

GEOLOGY.

Much of the description herewith presented, as well as the greater part of the mapping, have been taken from the paper by Miss Bascom, above noted, which left little to be desired as to our understanding of the geology of the district. A somewhat different interpretation of certain of the igneous rocks is suggested, however, and a more detailed inquiry directed toward the probable origin of the copper ores.

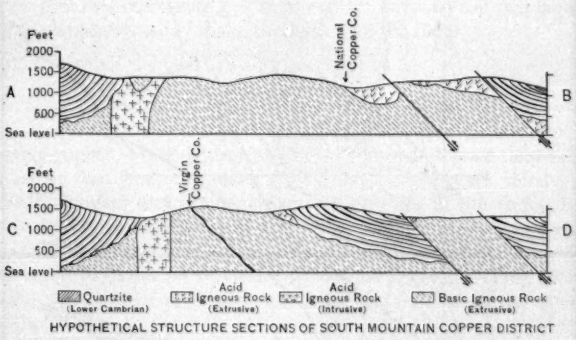
Three distinct formations are present,—a clastic rock, a basic igneous rock and an acid igneous rock. The first consists of a series of conglomerate and sandstone beds, capping the higher ridges and hills. The constituent grains are chiefly fragments of the igneous rocks now exposed in the valleys, over which it lies unconformably. Its thickness is not far from 1000 feet, and fossils it contains show it to be of Lower Cambrian age.

Since both of the igneous rocks are represented in the basal Cambrian conglomerates, they are both to be regarded as pre-Cambrian in age, although no definite correlation of them with formations of other regions is thereby implied. The basic rock is for the most part a dark green schistose material, to which the term greenstone may be appropriately applied. Locally it is massive, and then has the character of a basalt; and microscopic examination of the schistose portions show them to have been formed by metamorphism of the same rock. While chlorite is the usual dark silicate, epidote is also abundant in some places, and as the copper ores are largely associated with this mineral, its occurrence will be more fully described below. Numerous amygdules of quartz, epidote, or calcite testify to the original effusive character of the rock, and there can be no question that it represents an ancient lava flow.

The greater part of the acid igneous rock gives evidence of

a similar origin. The large northeastern body contains abundant amygdules, spherulites, lithophysæ, and various types of flow structures, all of which are characteristic of lavas. Certain isolated masses show, however, none of these features, but are instead quartz porphyries, and these have been distinguished on the accompanying maps, being regarded as dikes rather than overflow sheets.

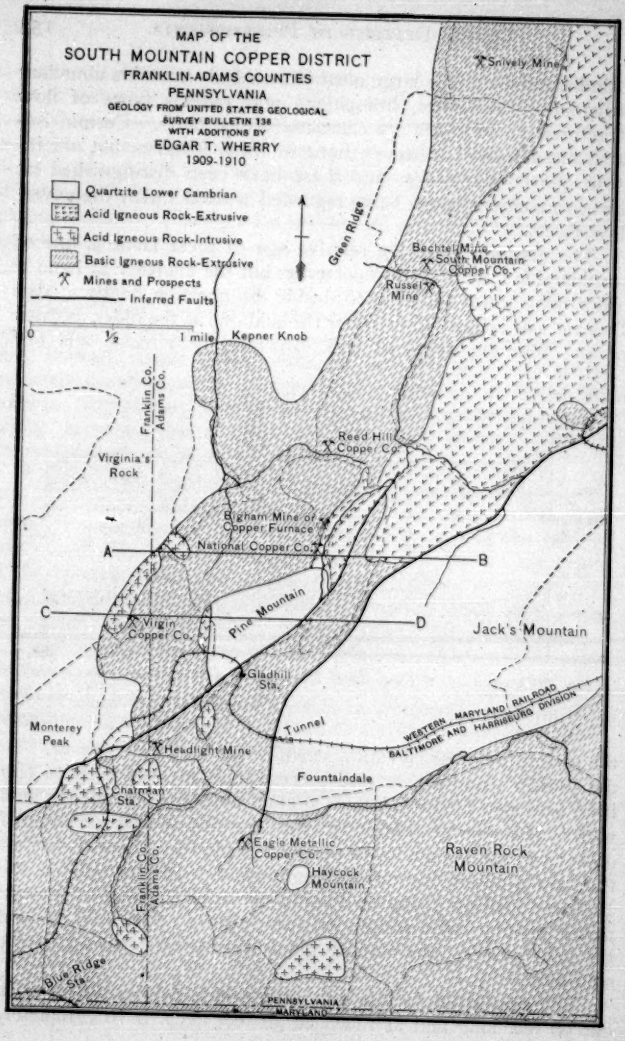
The question as to the relative age of these lavas is one of considerable interest and importance, but the evidence at hand is unfortunately not sufficient to decide the question finally. Miss Bascom was inclined to consider the acid one as the older, because of (*a*) four exposures of basic overlying acid rocks, and (*b*)



HYPOTHETICAL STRUCTURE SECTIONS OF SOUTH MOUNTAIN COPPER DISTRICT

the generally higher elevation at which the basic rocks occur. In the present paper the reverse succession is favored because (*a*) in at least two of the points of contact above mentioned the acid rock is of the quartz porphyry type regarded as characteristic of dikes; (*b*) the higher levels at which basic rocks appear may be the results of folding or faulting; and (*c*) at one locality, the National Copper Company's mine, there has recently been exposed a contact of typically extrusive phases of both rocks, and the acid overlies, the contact plane dipping 30 degrees to the southeast.

The greenstone in this exposure, which consists of an open cut 50 feet long and as much as 30 feet deep, is so completely


MAP OF THE
SOUTH MOUNTAIN COPPER DISTRICT
FRANKLIN-ADAMS COUNTIES
PENNSYLVANIA
GEOLOGY FROM UNITED STATES GEOLOGICAL SURVEY BULLETIN 138
WITH ADDITIONS BY
EDGAR T. WHERRY
1909-1910
Quartzite Lower Cambrian
Acid Igneous Rock-Extrusive
Acid Igneous Rock-Intrusive
Basic Igneous Rock-Extrusive
Mines and Prospects
Inferred Faults
0 ½ 1 mile
Green Ridge
Snively Mine
Bechtel Mine
South Mountain Copper Co.
Russel Mine
Kepner Knob
Franklin Co.
Adams Co.
Reed Hill Copper Co.
Virginia's Rock
Bigham Mine or Copper Furnace
National Copper Co.
A
B
C
D
Pine Mountain
Virgin Copper Co.
Jack's Mountain
Gladhill Sta.
WESTERN MARYLAND RAILROAD
BALTIMORE AND HARRISBURG DIVISION
Tunnel
Monterey Peak
Headlight Mine
Fountaindale
Chairman Sta.
Eagle Metallic Copper Co.
Haycock Mountain
Raven Rock Mountain
Franklin Co.
Adams Co.
Blue Ridge Sta.
PENNSYLVANIA
MARYLAND

sheared to a chlorite schist that its original character is indeterminable, but it shows some amygdules, and could well enough be the upper surface of a lava flow. The acid rock is a gray rhyolite yielding fine thin sections (several of which are figured in Miss Bascom's paper) showing an original spherulitic structure partially obscured by the development of quartz and feldspar in place of the ground mass, and elongated vesicles filled with epidote surrounded by a rim of quartz and occasionally containing grains of metallic copper. While these features suggest the top rather than the base of a lava flow, the under-rolling of a crust may bring vesicular phases to the base of an advancing lava sheet, or if composed of successive thin flows it might be vesicular throughout. There is thus nothing visible here opposed to the view that this represents a normal contact between the two lavas, which would certainly make the basic one the older.

ORE DEPOSITS.

MINERALOGY.—The most abundant and characteristic ore is native copper, which is present in every known deposit, and is in most of them the only mineral of value. It appears chiefly in small stringers and grains, traversing crevices in the rocks, but occasionally forms masses of large size, rounded lumps of several pounds in weight having occasionally been observed. So far as noted it shows no tendency to assume a crystal form of its own, the shape of the fragments being always that of the cavity occupied.

Chalcocite is not uncommon as minute scattered grains through the greenstones, but nowhere appears in sufficient quantity to constitute an ore. At the Eagle Metallic Copper Company's mine much of what was taken for chalcocite is actually specular hematite. Cuprite is present surrounding specks of native metal in the amygdules at the National Copper Company's property, and has probably been derived, like the associated carbonates, by partial weathering.

Malachite stains are evident everywhere at the outcrops of ore-bearing rocks, especially where chalcocite has been present; the native copper itself has rarely been affected by the atmosphere. Azurite and chrysocolla are less common, although at the National Mine their presence as thin films in joint cracks gives

rise to rather showy specimens. Minute crystals of both azurite and malachite occur here in some of the amygdules.

The most frequent associate of the copper minerals is epidote, which exists as a secondary replacement of the minerals of the greenstones, as well as a filling mineral in the amygdules. It is usually massive-granular, distinct crystals being quite exceptional. Cryptocrystalline vein-quartz is abundant, and the native copper is largely associated with it. Opaque white cleavable calcite is also present in some veins, notably at the Virgin Copper Co.'s Mine. Minute scales of specular hematite occur in the vein-quartz at several points, and as noted above have been mistaken for chalcocite at one mine. Asbestos in long silky fibres and dark green flaky chlorite complete the list of accessory minerals.

OCCURRENCE AND ORIGIN OF THE ORES.—While three types of occurrence of the copper minerals may be distinguished, there is no reason to suppose them to be distinct in origin, but on the contrary they show gradation from one to the other. In the first type grains of chalcocite are embedded in schistose chloritic greenstones, representing replacements of original silicates, or fillings in the amygdules. The malachite stains observable at so many exposures of the greenstones are in practically every case the result of the action of the weather on this class of material.

A second kind of deposit is the epidote vein type, which is represented in most of the mines of the region. It consists of layers or zones of greenstone high in calcium, so that the original rock constituents are largely replaced by epidote instead of chlorite, while the amygdules may be occupied by epidote or calcite. In these epidote-bearing layers there are numerous quartz veins, carrying native copper in relatively large amount; although the copper may also extend out into the rock itself, especially where it is shattered or otherwise porous.

In the third type, native copper and its alteration products occur in amygdules in the acid lavas near their lower contacts upon the basic ones. Stains also appear on the latter, however, and their cavities may contain the metal as well.

That the original source of the copper has been the basic lava now in the form of greenstone appears to be the most plausible interpretation of these deposits. The arguments in its favor consist in: (*a*) the practical limitation of the ore-bodies to this

rock; (*b*) the presence of minute amounts of copper as a constituent of its ferromagnesian minerals; (*c*) the similarity of this to other regions where such an origin is considered certain. Against it may be urged: (*a*) that in several places ores lie at or near contacts with the later acid volcanics, suggesting introduction of the metal by the latter; (*b*) that a complex and intricate motion of waters must apparently be appealed to in accounting for the concentration into the existing masses.

Taking up these points in order, the relation indicated in (*a*) is recognized by all who have had occasion to examine or prospect in the region. The appearance of green stains at nearly every exposure of the basic rocks, at least within the main area in the southwest portion of the region, and their total absence from the acid ones, except at one or two contact localities, is very striking. It might be suggested, to be sure, that some chemical feature of the former rocks, such as abundance of ferrous iron, has enabled them to act as a precipitant for copper, rising, perhaps, from a deep-seated source. There is, however, nothing in the distribution of the metal, and especially, no visible connection between its points of occurrence and prominent fissures, to justify such an assumption.

(*b*) With a view to determining to what extent copper is present in the basic lava itself, chemical examination was made of two samples, both taken from localities well removed from any known deposits of the metal. In one specimen 0.27, in the other 0.08 per cent. of copper were found; and as this proved to be insoluble in nitric acid, it cannot be due to disseminated chalcocite or native metal, but must be a constituent of the dark silicates of the rock.

As to (*c*), the similarity of these deposits to those of the Lake Superior Region is so marked that at least one early observer attempted exact correlation of the two occurrences.[4] And the resemblance to those in the Kotsina-Chitina Region, Alaska, as described by Moffit and Maddren,[5] is no less striking. While we can no longer agree with correlation on mineralogic or lithologic grounds of rocks so widely separated geographically, it can hardly be doubted that the chemical processes concerned in the concentration of the ores were closely analogous in the several cases, and the conclusions as to the source of the metal arrived at by those best qualified to judge with respect to one of these

localities are surely deserving of considerable weight in forming any theory as to another. Wadsworth, Lane, and many others agree in attributing the copper to the ferromagnesian constituents of the igneous rocks in the Lake Superior Region, even in the face of the known existence of occasional veins suggesting a deep-seated source; and a like interpretation would seem still more plausible here, in the absence of any well-defined fissures.

Objection (*a*), that many ore bodies occur at or near contacts of the two igneous rocks, is of little weight, since such nearness to the contact is for the most part only an accidental circumstance. Thus the deposit being explored by the Virgin Copper Company, while less than a hundred feet from such a contact, not only shows no connection with it as far as distribution of the metal goes, but is also identical in character with several others throughout the greenstone belt, some of which are far removed from any known mass of acid rock. While at the National Copper Company's mine, the only place where the actual contact relations are exposed, the metal occurs in both rocks, and might have originated in either one equally well.

A consideration of the process of concentration of the metal will show the weakness of objection (*b*) also. It may be regarded as probable that the copper has been introduced simultaneously with the vein quartz and calcite because of its intimate admixture with them. As Van Hise has pointed out,[6] the silica which fills up the great majority of crevices in rocks which have remained for any time in the "belt of cementation," that is, from between about 1000 and 30,000 feet below the surface, has been chiefly derived from the rocks nearer the surface, from which the carbon dioxide of the atmosphere has liberated silica in the colloidal state. The precipitation of this silica is, however, not so much a chemical as a physical process, the character of the material already present in the solid state determining the character of the substance separating, so that sand grains may be secondarily enlarged, and, in general, material originally distributed through a body of rock may gradually become segregated into a few large masses in obedience to the principle that large grains grow at the expense of small ones, without any circulation of water being called for, but only the operation of the process of diffusion.

If we admit that the quartz veins have been formed in this

way, it seems only reasonable that the same principles should apply to the so closely associated native copper. But we must first be certain that this interpretation does not disagree with the chemical features of the deposits. For example, the constant association of copper with epidote—a relation so evident that the epidotized layers are called by local prospectors "copper rock"—is it not possible that the epidote may have acted as a precipitant for the metal? Such a conclusion is, however, chemically unsound; epidote contains but small amounts of ferrous iron, and no other constituents capable of bringing about reduction, whereas the chlorite making up a considerable proportion of the body of the rock may carry as much as 10 per cent. FeO, which should render it far more effective as a reducing agent. A little reflection shows, on the other hand, that the association of the copper and epidote may be entirely a physical phenomenon. During the intense earth movements to which the region has been subjected, the chloritic portions of the rock mass have "flowed," producing the southeast dipping lamination everywhere apparent; while the layers rendered hard and brittle by the presence of the epidote have been, by the same forces, cracked and shattered, the open spaces thus produced being filled by vein quartz and copper simply because they were open spaces.

The existence of the greater amount of copper as the native metal rather than as a compound is also, here as in the Lake Superior and the Alaska district, in need of explanation. The view held by Pumpelly[7] and others, and experimentally verified by Stokes,[8] that ferrous compounds can reduce copper to the metallic state, is unquestionably an adequate cause of this condition, yet we do not find the metal surrounding masses of ferrous minerals, but, embedded as it is in vein quartz in turn surrounded by epidote, it is about as far removed from them as it could possibly get. The only reasonable explanation of this state of affairs is that the copper has not been transported as sulphate, as commonly assumed, and deposited by reduction, but has been carried to its present position as a dilute solution of the metal itself, the reducing power of the ferrous iron having made itself felt at the time of breaking up of the original copper-bearing silicates. The process of diffusion is thus sufficient to account for the segregation of the metal into the existing masses, without

need for appeal to a circulation of solutions or any specific cause for precipitation. The presence of chalcocite at some localities fits in as well with this theory as with any other; it is of course difficult to account for the origin of the sulphur, but surely the original igneous rocks contained sulphides of some sort, even original chalcocite being by no means excluded by failure to observe it in the few samples examined.

DESCRIPTION OF PROPERTIES.—The position of the various prospects is indicated on the accompanying sketch map, which is chiefly copied from that in U.S.G.S. Bulletin 136, with the few changes noted above. The majority have been started at the outcrop of one of the numerous epidote-bearing layers in the greenstone, which frequently show copper stains where exposed at the surface. The hope has evidently been that the percentage of metal would increase in depth, but this does not seem to have been realized, since the openings have mostly been allowed to fill with water and cave in. Assays indicating valuable deposits were frequently obtained, as recorded in the literature, but these appear to have been without exception made on picked specimens, and there is no record of anything like an adequate sampling of any of the ore bodies.

The Russell Mine, consisting of a large shaft 120 feet deep, is being kept pumped out by the Reed Hill Copper Company, although no actual work is going on. The same company has a drift extending some 100 feet northward into the hill, about a mile further south, but here also operations are suspended.

In the summer of 1907 the Virgin Copper Company began prospecting with diamond drill on property located by Mr. Charles E. Wills, of Fountaindale. The bed of epidote rock outcropping on the western slope of a small ridge was 8 inches thick, and dipped about 45 degrees eastward. The drilling indicated an increase in thickness in depth, and accordingly in the spring of 1908 a slope was begun above the point of outcrop, and has been driven downward in the soft chlorite schist overlying the epidote layer.

It has thus far been continued over 250 feet, and cross cuts have been driven back under the slope at the 150, 200, and 250 foot levels, all of them proving the continuity of the epidote bed without apparent decrease in copper content. The writer's estimates of the proportion of copper in the quartz-calcite vein

material, as exposed in the upper cross cut, gave 10 per cent., and as this vein material certainly makes up less than 10 per cent. of the epidote rock, the ore can hardly carry more than 1 per cent. of metal, an amount not workable at a profit. Should, however, the percentage of copper in the veins, or the proportional amount of them, increase in depth, a workable body might be obtained, and it was hoped that geological examination would throw some light on the probability of such an outcome.

Bearing in mind the probable manner of deposition of the metal discussed above, it will be seen that the first of these possibilities is excluded. Since the metal and the quartz were formed simultaneously and by the same processes, no change in their relative amounts is to be expected. On the other hand, it is quite possible for the proportion of vein material in the epidote rock to increase, since it is determined by the degree of shattering which the rock has undergone, and this would be greatest at the point of greatest deformation of the rocks of this particular area, which might equally well be 1000 feet down as at the present surface of the ground. There is, however, nothing about the distribution of the various rocks at the surface which can give any clue to this problem; the only way to decide it is by exploration such as is now being carried on. So all estimates as to the probable value of the property must be reserved until the behavior of the epidote layer with increasing depth can be determined.

The other mines in the region are less promising. The Eagle Metallic Copper Company started work in 1904 about a mile southeast of the locality just described, following a similar epidote layer over 300 feet at an inclination of 30°. After passing the oxidized zone the quartz veins were found to contain occasional small grains of chalcocite, and an abundance of specular hematite. No workable ore appears to have been obtained, and the slope is now full of water. A similar state of affairs was found to exist at the various other points indicated on the map, and it would seem that the future of the district depends largely on the results of the explorations of the Virgin Copper Company. In view of the commendable manner with which they are going about this work, and considering the interest which would attach to a working copper mine in so easily accessible a region in the eastern part of the country, they are certainly to be wished every success.

SUMMARY OF CONCLUSIONS.

The region is occupied by two pre-Cambrian effusive igneous rocks, a rhyolite and a basalt, both considerably altered. The latter was probably the first to form, the acid rock being in part in dikes cutting through it, and a contact exposed during recent mining operations showing a rhyolite lava overlying basalt. The deposits consist chiefly of native copper in quartz veins in epidotized layers in the basalt lava. It is believed that the metal was originally distributed throughout this rock and has been concentrated, like the associated quartz, by diffusion, in obedience to the principle that large crystals grow at the expense of small ones; that the copper was reduced by the ferrous iron of the rock constituents, and transported as a dilute solution of free metal; and that the association with epidote is of physical rather than of chemical significance, in that the epidotized layers were the only ones of sufficiently resistant character to permit of the development of open cracks during the regional metamorphism. The workability of the deposits depends upon the possible increase of these quartz veins in depth, but it seems impossible to predict this from surface indications, and extended exploration is thought to be the only way to settle the question as to the future of the district.

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Williams, G. H.: The Volcanic Rocks of South Mountain in Pennsylvania and Maryland. Amer. Jour. Sci., 1892, (3) xliv, p. 482.

Poles Purchased in 1909.—The total number of poles reported to the Bureau of the Census as purchased during the calendar year 1909 by the telegraph and telephone companies, steam and electric railroads, and electric light and power companies of the United States was 3,739,000, as against 3,249,000 in 1908 and 3,283,000 in 1907. There were purchased in 1909 by the same class of users 3,509,000 cross-arms, 6,168,000 brackets, and 18,463,000 insulator pins. Cross-arms, brackets, and insulator pins were not included in the annual census of lumber and timber products prior to 1909.

This information appears in a preliminary comparative report covering 1909, 1908, and 1907, which was transmitted to Census Director Durand by Chief Statistician William M. Steuart, under whose supervision it was prepared by J. E. Whelchel, expert special agent of the Division of Manufactures. In co-operation with the Forest Service of the Department of Agriculture, the Bureau of the Census annually collects and publishes statistics pertaining to the group of lumber and timber industries.

Telephone and telegraph companies reported purchases during 1909 of 2,916,000 poles, or 78 per cent. of the total. This was an increase over 1908 in the number reported as bought by this class of users of 354,000 poles, or 14 per cent., and over 1907 of 604,000 poles, or 26 per cent. Steam railroads reported the purchase of 26 per cent. more poles in 1909 than in 1908, though 34 per cent. less than in 1907, while the reported purchases by electric railroads and electric light and power companies were 18 per cent. greater than in 1908 and 7 per cent. less than in 1907.

There was little change in the average cost per pole of all lengths and from all species of wood in 1909, as compared with 1908, it being $1.89 in the later and $1.82 in the earlier year. The

average cost per pole, $2.46, in 1907, was substantially larger than in either of the later years, mainly for the reason that a class of pole consumers in the United States which uses chiefly short poles was not included in the census for 1907.

Cedar continues to be the principal pole timber, contributing 65 per cent. of the total purchases in 1909, 68 per cent. in 1908, and 64 per cent. in 1907. Chestnut, after cedar, was used in greatest quantity in all three years, forming 16 per cent. of the total in 1909, 16 per cent. in 1908, and 19 per cent. in 1907. Among the remaining species, the increase in the number of oak poles reported as purchased during the last three years is noteworthy; more than three times as many poles from this species have been reported as purchased during 1909 as was the case in 1907.

Substantial progress in the practice of treating poles with chemicals to preserve them from decay is disclosed by the returns for 1909, nearly one-sixth of the total purchases during that year having been given some preservative treatment, as against about one-tenth in 1908 and one-eighth in 1907.

Of the total outlay during 1909, $1,621,000, for cross-arms, brackets, and insulator pins, the telegraph and telephone companies contributed 63 per cent., electric railroads and electric light and power companies 32 per cent., and steam railroads 4 per cent.

The comparative summary follows:

THE SUMMARY OF POLES PURCHASED.

Kinds of Wood.	1909		1908		1907	
	Number.	Cost.	Number.	Cost.	Number.	Cost.
Cedar	2,440,000	4,680,000	2,200,000	3,781,000	2,109,000	5,203,000
Chestnut	608,000	1,383,000	516,000	1,227,000	630,000	1,620,000
Oak	237,000	137,000	161,000	95,000	76,000	60,000
Pine	180,000	520,000	117,000	383,000	156,000	460,000
Cypress	78,000	117,000	91,000	148,000	100,000	308,000
Juniper	44,000	79,000	42,000	83,000	39,000	109,000
Tamarack	30,000	18,000	24,000	12,000	14,000	10,000
Douglas fir	25,000	35,000	20,000	80,000	16,000	41,000
Redwood	23,000	49,000	13,000	39,000	31,000	109,000
Bois d'Arc	21,000	9,000	18,000	11,000	6,000	3,000
Spruce	11,000	18,000	8,000	23,000	11,000	29,000
Locust	10,000	9,000	10,000	8,000	5,000	4,000
All other	32,000	19,000	29,000	18,000	89,000	126,000
Total	3,739,000	$7,074,000	3,249,000	$5,929,000	3,283,000	$8,082,000

Power House Economies. (*Iron Age*, lxxxvi, 15.)—The offer of $5000 as prizes in a competition between warships for showing economy, resulted in saving $1,000,000 in a year. The presumption is that the engineering staffs of the ships were ordinarily watchful of extravagance before the system of economy was inaugurated, yet it is evident there was much waste. This is suggestive of the possible economies in the power-houses of manufacturing plants.

PROPERTIES OF DRY, SATURATED AND UNSATURATED AIR; WITH APPLICATION TO COOLING-TOWER AND EVAPORATIVE SURFACE CONDENSER CALCULATIONS.

BY

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AIR is said to be saturated when it contains all the water vapor it can hold at the existing temperature without causing precipitation. If the air is only partially saturated it will tend to become saturated by absorbing moisture from surrounding objects. The drier the air the greater will be its affinity for moisture. The necessary heat to effect vaporization is supplied directly by the water producing the vapor or by the surrounding objects in contact with the water. Thus, in the open cooling tower the vapor is absorbed from the circulating water, and the heat necessary to cause this evaporization is given up by the circulating water itself; and in the evaporative surface condenser the vapor is absorbed from the water spray in contact with the tubes, the heat required to effect this vaporization being given up by the steam within the condenser proper, resulting in condensation of the steam. If the air is very dry and at a high temperature the vaporization of the water may be rapid enough to cool the remaining water to a temperature much lower than that of the air. In this case practically all of the cooling is affected by *evaporation*. But when the air is at a low temperature and nearly saturated a considerable amount of heat may be carried away by *conduction*. Except in the case of perfectly dry air, isolated from moisture in any form, the cooling process results in a loss of water, which for all practical purposes cannot be reclaimed. Atmospheric air is never dry and is seldom saturated even during a severe thunder shower.

If air is only partially saturated the ratio of the weight of water present to that required for complete saturation at the given temperature and pressure is called the *relative humidity*. The latter also represents the ratio of the existing vapor tension

to the maximum tension at the same temperature. The degree of saturation, or relative humidity, is ordinarily determined from the difference in reading of a wet and dry bulb thermometer, thus: If the air is completely saturated no evaporation takes place from the wet bulb and the two thermometers give identical readings; but if it is unsaturated, evaporation takes place, the wet bulb thermometer is cooled and its reading is lower than that of the dry bulb. The difference in reading is a function of the relative humidity and the latter may be obtained from "Hygrometric Tables" or calculated by means of the following modification of Apjohn's formula:

If the thermometer reads above 32° F.,

$$h=\left(P_w-\frac{dP}{2640}\right)\frac{100}{P_d}. \qquad (1)$$

If the thermometer reads below 32° F.,

$$h=\left(P_w-\frac{dP}{2880}\right)\frac{100}{P_d}. \qquad (2)$$

in which

h = relative humidity, per cent.;
d = difference in reading of the wet and dry thermometers, degrees F.;
P = barometric pressure, inches of mercury;
P_w = maximum tension of aqueous vapor corresponding to the temperature of the wet thermometer, inches of mercury (this may be obtained directly from Steam Tables);
P_d = maximum tension of aqueous vapor corresponding to the temperature of the dry thermometer, inches of mercury.

Example.—Determine the relative humidity when the dry bulb reads 80° F., wet bulb 60° F., barometer 29.5.

From Steam Tables:

$$P_w=0.522;\quad P_d=1.029;$$

$$h=\left(0.522-\frac{(80-60)29.5}{2640}\right)\frac{100}{1.029}=29 \text{ per cent.}$$

The design of condensers, dry kilns, cooling-towers and heating and ventilating apparatus is greatly facilitated by the use of "Saturated Air Tables." A convenient form is illustrated in Table I. The factors involved in this table are based upon the following fundamental physical laws:

Dalton's Laws.—(1) The mass of a given kind of vapor required to saturate a given space at a given temperature is the same whether the vapor is all by itself or associated with vaporless gases. (2) The maximum tension of a given kind of vapor at a given temperature is the same whether it is all by itself or associated with vaporless gases. (3) In a mixture of gas and vapor the total pressure is equal to the sum of the partial pressures.

These laws may be expressed:

For saturated air

$$P = P_1 + P_v \quad (3)$$
$$d = d_1 + d_v \quad (4)$$

For unsaturated air

$$P = P_1 + hP_v \quad (5)$$
$$d = d_1 + hd_v \quad (6)$$

in which

P = observed atmospheric pressure as obtained from the barometer;
P_1 = pressure of the dry air in the mixture;
P_v = pressure of the vapor in the mixture. (This may be taken from Steam Tables. It is the pressure of the steam at the temperature corresponding to that of the mixture of air and vapor.)
d = density or weight per cubic foot of the mixture at a given P and t;
d_1 = density of dry air at pressure P_1 and temperature t;
d_v = density of vapor at pressure P_v and temperature t. (This may be taken directly from Steam Tables.)

Densities, pressures and temperatures are conveniently taken in pounds, inches of mercury absolute, and degrees Fahrenheit, respectively.

Charles's Law.—All gases expand equally when heated at constant pressures and for every degree Fahrenheit the amount of expansion is $\frac{1}{459.6}$ of the volume occupied at 0° F., or $\frac{1}{459.6 + t}$ of the volume occupied at any temperature "t." For most purposes this may be taken as $\frac{1}{460 + t}$.

For unsaturated water vapor the law is approximately true, the deviation being greatest as the saturation point is approached.

TABLE I.—PROPERTIES OF

MIXTURE OF AIR SATURATED

Temperature, degrees F.	Weight of 1000 cu. ft. of dry air, pounds	Volume of one lb. of dry air, cu. ft.	Elastic force of vapor, inches of mercury (Marks & Davis)	Elastic force of the dry air in the mixture, inches of mercury	Weight of 1000 cu. ft., pounds		
					Weight of the dry air, content	Weight of the vapor, content	Total weight of the mixture
1	2	3	4	5	6	7	8
0	86.35	11.58	*0.044	29.88	86.23	0.081	86.31
10	84.51	11.83	*0.069	29.85	84.31	0.125	84.43
20	82.75	12.08	*0.107	29.81	82.44	0.189	82.63
30	81.06	12.33	*0.156	29.76	80.62	0.273	80.89
32	80.73	12.39	0.180	29.74	80.24	0.304	80.54
35	80.24	12.46	0.203	29.72	79.70	0.340	80.04
40	79.43	12.59	0.248	29.67	78.77	0.410	79.18
45	78.64	12.72	0.300	29.62	77.86	0.492	78.35
50	77.88	12.84	0.362	29.56	76.94	0.587	77.53
55	77.12	12.97	0.436	29.48	75.98	0.700	76.68
60	76.38	13.09	0.522	29.40	75.05	0.828	75.88
62	76.08	13.14	0.560	29.36	74.66	0.885	75.54
65	75.65	13.22	0.622	29.30	74.08	0.977	75.06
70	74.94	13.34	0.739	29.18	73.08	1.15	74.23
72	74.65	13.40	0.790	29.13	72.68	1.22	73.90
75	74.24	13.47	0.873	29.05	72.08	1.35	73.42
80	73.55	13.60	1.03	28.89	71.01	1.57	72.58
85	72.87	13.72	1.21	28.71	69.92	1.83	71.75
90	72.21	13.85	1.42	28.50	68.78	2.13	70.91
95	71.56	13.97	1.66	28.26	67.59	2.47	70.06
100	70.92	14.10	1.93	27.99	66.34	2.85	69.19
105	70.29	14.23	2.24	27.69	65.05	3.28	68.33
110	69.67	14.35	2.59	27.33	63.64	3.77	67.41
115	69.07	14.48	2.99	26.93	62.16	4.31	66.47
120	68.47	14.61	3.44	26.48	60.60	4.92	65.52
125	67.88	14.73	3.95	25.97	58.92	5.61	64.53
130	67.31	14.86	4.52	25.40	57.14	6.37	63.51
135	66.74	14.98	5.16	24.76	55.23	7.21	62.44
140	66.19	15.11	5.88	24.04	53.18	8.14	61.32
145	65.64	15.23	6.67	23.25	51.01	9.18	60.19
150	65.10	15.36	7.57	22.35	48.63	10.32	58.95
155	64.57	15.49	8.55	21.37	46.12	11.57	57.69
160	64.05	15.61	9.65	20.27	43.39	12.96	56.35
165	63.54	15.74	10.86	19.06	40.47	14.48	54.95
170	63.04	15.86	12.20	17.72	37.33	16.14	53.47
175	62.54	15.99	13.67	16.25	33.96	17.96	51.92
180	62.05	16.12	15.29	14.63	30.34	19.94	50.28
185	61.57	16.24	17.07	12.85	26.44	22.10	48.54
190	61.09	16.38	19.02	10.90	22.26	24.44	46.70
195	60.63	16.50	21.15	8.77	17.17	27.00	44.77
200	60.17	16.62	23.47	6.45	12.97	29.76	42.73
205	59.71	16.74	26.00	3.92	7.82	32.76	40.58
210	59.27	16.86	28.76	1.16	2.30	35.97	38.27
212	59.09	16.92	29.92	0	0	37.32	37.32

* Regnault.

SATURATED AIR. (BAROMETER 29.921.)

WITH WATER VAPOR

Ratio of dry air to water vapor	Weight of water necessary to saturate 100 lbs. of dry air	Cu. ft. of vapor from one lb. of water at pressure, as in column 4	B.T.U. absorbed by 1000 cu. ft. of dry air per degree F.	B.T.U. absorbed by 1000 cu. ft. of saturated air per degree F.	Cu. ft. of dry air warmed one degree F., per B.T.U.	Cu. ft. of saturated air warmed one degree F., per B.T.U.	Temperature, degrees F.
9	10	11	12	13	14	15	16
1064.0	0.094	.....	20.51	20.52	48.75	48.74	0
674.0	0.148	.....	20.07	20.08	49.80	49.79	10
436.0	0.229	.....	19.65	19.67	50.89	50.84	20
295.0	0.338	.....	19.25	19.27	51.94	51.89	30
264.0	0.379	3294.0	19.17	19.19	52.16	52.11	32
234.0	0.468	2938.0	19.06	19.08	52.47	52.41	35
192.0	0.521	2438.0	18.86	18.89	53.02	52.94	40
159.0	0.632	2038.0	18.68	18.72	53.53	53.42	45
131.0	0.763	1702.0	18.49	18.54	54.04	53.94	50
108.0	0.921	1430.0	18.31	18.37	54.61	54.43	55
91.0	1.10	1208.0	18.14	18.20	55.12	54.94	60
85.0	1.18	1130.0	18.07	18.13	55.33	55.16	62
76.0	1.32	1024.0	17.96	18.03	55.68	55.53	65
64.0	1.57	871.0	17.80	17.88	56.18	55.93	70
59.0	1.68	817.0	17.74	17.82	56.36	56.12	72
54.0	1.87	743.0	17.63	17.74	56.71	56.37	75
45.0	2.21	637.0	17.47	17.59	57.23	56.85	80
38.0	2.62	546.0	17.31	17.45	57.77	57.30	85
32.0	3.08	469.0	17.14	17.31	58.34	57.77	90
27.0	3.65	405.0	17.00	17.20	58.82	58.14	95
23.0	4.29	351.0	16.84	17.06	59.38	58.62	100
20.0	5.04	305.0	16.69	16.96	59.92	58.96	105
17.0	5.92	266.0	16.54	16.85	60.46	59.35	110
14.0	6.93	232.0	16.40	16.74	60.97	59.74	115
12.0	8.12	203.0	16.26	16.65	61.50	60.06	120
11.0	9.46	178.0	16.12	16.57	62.03	60.35	125
9.0	11.20	157.0	15.98	16.50	62.58	60.61	130
7.7	12.90	139.0	15.85	16.41	63.09	60.93	135
6.5	15.30	123.0	15.72	16.37	63.61	61.08	140
5.5	17.90	109.0	15.59	16.33	64.14	61.23	145
4.7	21.70	96.9	15.46	16.29	64.68	61.38	150
4.0	25.10	86.4	15.33	16.27	65.23	61.46	155
3.3	29.90	77.2	15.21	16.26	65.75	61.50	160
2.8	35.80	69.1	15.09	16.27	66.27	61.46	165
2.3	43.20	62.0	14.97	16.29	66.80	61.38	170
1.9	54.80	55.7	14.85	16.33	67.34	61.23	175
1.5	65.70	50.1	14.74	16.38	67.84	61.05	180
1.2	83.80	45.2	14.62	16.44	68.40	60.83	185
0.91	111.0	40.9	14.51	16.53	68.92	60.49	190
0.66	191.0	37.0	14.40	16.64	69.44	60.96	195
0.44	229.0	33.6	14.29	16.77	69.98	59.63	200
0.24	419.0	30.5	14.18	16.92	70.52	59.10	205
0.06	.....	27.8	14.07	17.09	71.07	58.58	210
0	.....	26.8	14.03	17.16	71.33	58.27	212

For saturated water vapor the law is not applicable and recourse must be had to Steam Tables.

This law may be expressed:

$$V_1 = V \times \frac{t_1 + 460}{t + 460}; \tag{7}$$

$$d_1 = d \times \frac{t + 460}{t_1 + 460}; \tag{8}$$

in which

V_1 = volume of gas at temperature t_1 and constant pressure;
V = volume of gas at temperature t and constant pressure;
d_1 = density of gas at temperature t_1 and constant pressure;
d = density of gas at temperature t and constant pressure.

Boyle's Laws.—The volume occupied by a given mass of gas under different pressures is inversely proportional to the pressure provided the temperature remains constant.

For unsaturated water vapor the law is approximately true, the deviation increasing as the saturation point is reached.

For saturated water vapor this law is not applicable and recourse must be had to Steam Tables.

This law may be expressed:

$$PV = P_1 V_1 \tag{9}$$

$$Pd_1 = P_1 d \tag{10}$$

(Notations as above.)

Laws of Charles and Boyle Combined.—When pressure and temperature both change, we have

$$V = V_1 \frac{P_1(t + 460)}{P(t_1 + 460)}; \tag{11}$$

$$d = d_1 \frac{P(t_1 + 460)}{P_1(t + 460)}. \tag{12}$$

Practically all the problems involving the use of gases, dry, saturated or partially saturated, may be conveniently solved by means of equations (1) to (12).

The different items in Table I will be calculated in order to show the application of the various physical laws.

Standard atmospheric pressure is taken as 29.921 inches of mercury or 14.7 pounds per square inch and all steam and air tables are based upon it. We will assume that Steam Tables

are available and that the density of air at 0° F., pressure 29.921, is known, or $d = 0.086^{35}$.

Let us determine the various properties corresponding to, say, a temperature of 100° F., and standard atmospheric pressure.

Column 2.

From equation (8)

$$d_1 = d\left(\frac{t+460}{t_1+460}\right)$$
$$= 0.086^{35}\left(\frac{0+460}{100+460}\right)$$
$$= 0.07092 = \text{density of one cubic foot of } dry \text{ air under the required conditions.}$$

The various items in the column have been multiplied by 1000 to avoid unwieldly decimals.

Column 3.

The figure in this column is the reciprocal of the density of one cubic foot at 100° F., thus:

$$V_1 = \frac{1}{d_1} = \frac{1}{0.07092}$$
$$= 14.1 = \text{cubic feet per pound of dry air under the required conditions.}$$

Column 4.

The figure in this column is taken directly from the Steam Tables.

Column 5.

From equation (3)

$$P = P_1 + P_v$$
$$29.921 = P_1 + 1.93$$

From which

$P_1 = 27.99 =$ tension or elastic force of the dry air in the mixture.

Column 6.

From equation (9)

$$Pd_1 = P_1 d$$
$$29.921\ d_1 = 27.99 \times 0.07092$$

or, $d_1 = 0.06634 =$ weight of dry air in one cubic foot of the saturated mixture. Weight of 1000 cubic feet = 66.34 pounds.

Column 7.

From Steam Tables we find the density of one cubic foot of water vapor at 100° F., to be

$$d_v = 0.00285 \text{ lbs.}$$

The weight of 1000 cubic feet = 2.85 lbs.

Column 8.

From equation (5)

$d = d_v + d_1$

$= 0.00285 + 0.06634$

$= 0.06919 =$ weight of one cubic foot of the saturated mixture.

Weight of 1000 cubic feet $= 69.19$ lbs.

Column 9.

$\frac{d_1}{d_v} = \frac{0.06634}{0.00285} = 23 =$ ratio of dry air to water vapor in a saturated mixture.

Column 10.

$\frac{d_v}{d_1} = \frac{0.00285}{0.06634} = 0.0429 =$ ratio of water vapor to dry air or the weight of vapor necessary to saturate one pound of dry air.

Vapor required to saturate 100 pounds of dry air $= 4.29$ lbs.

Column 11.

This is the specific volume of saturated steam at the given temperature and may be obtained directly from the Steam Tables.

Column 12.

B.T.U. absorbed = weight of 1000 cubic feet of dry air times specific heat.

B.T.U. $= 70.92$ (column 2) times $0.2375 = 16.84$.

Column 13.

1000 cubic feet of mixture at 100° F., contains 66.34 pounds of dry air (column 6) and 2.85 pounds of water vapor (column 7).

B.T.U. absorbed by the dry air $= 66.34 \times 0.2375 = 15.76$

B.T.U. absorbed by the vapor $= 2.85 \times 0.46 = 1.30$

B.T.U. absorbed by the saturated mixture $= 17.06$

0.46 is taken as the specific heat of water vapor under the given conditions.

Columns 14 and 15 are reciprocals of the B.T.U. absorbed per pound of dry and saturated air, respectively.

PRACTICAL APPLICATION.

Closed Cooling-Tower.—Determine the quantity of air and "make up water" necessary to cool 10000 pounds of water per hour from 120 to 80° F., with operating conditions as follows: Temperature of the air entering and leaving the tower,

70 and 110° F., respectively; relative humidity of the air entering and leaving the tower 70 and 95 per cent. respectively; barometric pressure 29.52 inches.

The heat H_t to be withdrawn in order to cool 10000 pounds of water per hour from 120 to 80° F., is

$$Ht = 10000\ (120 - 80) = 400{,}000 \text{ B.T.U.}$$

Neglecting radiation, leakage and other minor losses this heat is dissipated (1) in raising the temperature of the entering air and its vapor content from 70 to 110° F., and (2) in evaporating the moisture absorbed by the air in passing through the tower.

Heat Absorbed by the Dry Air.—The pressure of the dry air in the atmospheric air entering the cooling tower, is (equation 5)

$$\begin{aligned} P_1 &= P - hP_v \\ &= 29.52 - 0.7 \times 0.74 \\ &= 29.0. \end{aligned}$$

Similarly the pressure of the dry air leaving the tower is

$$\begin{aligned} P_2 &= 29.52 - 0.95 \times 2.591 \\ &= 27.06. \end{aligned}$$

If V = column of atmospheric air in thousands of cubic feet entering the tower, its volume will be increased to 1.15 V on leaving the tower because of the increase in temperature and decrease in pressure, thus (equation 11)

$$V_1 = \frac{29}{27.06} \times \frac{460 + 110}{460 + 70} = 1.15\, V.$$

The weight of w' of dry air entering the cooling tower is

$$\begin{aligned} w' &= d \frac{P_1}{P} V \\ &= 74.94 \frac{29.0}{29.92} V \\ &= 72.7 V \text{ lbs.} \end{aligned}$$

(74.94 = density of 1000 cu. ft. of dry air at 70° F., and 29.92 inches pressure. See column 2, Table I.)

The heat H' required to heat w' lbs. of dry air from 70 to 110° is

$$H' = 0.24\ w\ (110-70)$$
$$= 0.24 \times 72.7\ V \times 40$$
$$= 698\ V \text{ B.T.U.}$$

The weight w_0 of vapor carried into the tower with the air is

$$w_0 = 0.70 \times 1.15\ V$$
$$= 0.805\ V \text{ lbs.}$$

(0.70 = relative humidity and 1.15 = weight of water vapor in 1000 cu. ft. of saturated air at 70° F. See column 7, Table I.)

The heat H_0 required to superheat w_0 lbs. of vapor from 70° to 110° F., is

$$H_0 = w_0 \times 0.46\ (110-70)$$
$$= 0.805\ V \times 0.46 \times 40$$
$$= 14.8\ V \text{ B.T.U.}$$

The weight w of vapor discharged from the top of the tower is

$$w' = 1.15V \times 0.95 \times 3.77$$
$$= 4.119V \text{ lbs.}$$

($1.15\ V$ = volume of air discharged from the top of the tower; 0.95 = its relative humidity; 3.77 = weight of water vapor in 1000 cu. ft. of saturated air at 110° F.)

The amount evaporated, w, or the "make up water" is

$$w = w_1 - w_0$$
$$= 4.119\ V - 0.805\ V$$
$$= 3.31\ V \text{ lbs.}$$

The heat H required to evaporate w lbs. of water at 110° F. is

$$H = 1030\ w$$
$$= 1030 \times 3.31\ V$$
$$= 3409\ V.$$

The total heat H_t absorbed by the air and its vapor content in passing through the tower is

$$H_t = H_0 + H + H'$$
$$= 14.8\ V + 3409\ V + 698\ V$$
$$= 4122\ V.$$

But this represents also the heat abstracted from the circulating water, or

$$4122 = V400{,}000$$

$V = 97.0$ thousands of cubic feet of atmospheric air necessary to cool one thousand pounds of water under the given conditions.

The water evaporated or the "make up water" is

$$w = 3.31\ V$$
$$= 3.42 \times 97$$
$$= 321 \text{ pounds.}$$

The per cent. of circulating water lost by evaporation is

$$100 \frac{321}{10{,}000} = 3.2.$$

Evaporative Surface Condenser.—How many cubic feet of air and how many pounds of water spray must be forced through an evaporative surface condenser of the fan type in order to condense 1000 pounds of steam per hour and maintain a vacuum of 24.5 inches, barometer 29.5 (atmospheric air 80° F., relative humidity 70 per cent.); air and vapor issuing from the discharge pipe under pressure of four inches of water, temperature 125° F., relative humidity 98 per cent.?

The absolute pressure in the condenser is

$$29.5 - 24.5 = 5 \text{ inches of mercury.}$$

The total heat to be withdrawn in order to condense 1000 pounds of steam per hour at absolute pressure of 5 inches is

$1000 \times 1020.8 = 1{,}020{,}800$ B.T.U.
(1020.8 being the latent heat of vaporization at this pressure.)

Neglecting radiation and leakage losses, this is the heat to be abstracted per hour by the air and water spray.

The pressure of the dry air in the mixture entering the condenser is

$$P_1 = 29.5 - 0.7 \times 1.029$$
$$= 28.78.$$

The pressure of the dry air in the mixture leaving the condenser is

$$P_2 = (29.5 + 0.294) - 0.98 \times 3.95$$
$$= 25.92.$$ (0.294 is the fan pressure in inches of mercury.)

The volume of air V_1 leaving the condenser will be greater than the volume V (thousands of cu. ft. per hour) entering on account of the reduction in pressure and the increase in temperature, thus:

$$V_1 = \frac{28.78}{25.92} \times \frac{460 + 125}{460 + 70} V$$
$$= 1.22V.$$

The weight of vapor w_0 brought in with the atmospheric air is

$$w_0 = 0.7 \times 1.57\ V$$
$$= 1.1\ V \text{ lbs.}$$

The weight of vapor w_1 in the discharge is

$$w = 1.22\ V \times 5.61 \times 0.98$$
$$= 6.58 \text{ lbs.}$$

The amount evaporated is

$$w = w_1 - w_0$$
$$= 6.58\ V - 1.1\ V$$
$$= 5.48\ V \text{ lbs.}$$

The heat H_0 required to superheat w_0 lbs. of water vapor from 80° to 125° F., is

$$H_0 = 0.46 \times w_0\ (125 - 80)$$
$$= 0.46 \times 1.1V \times 45$$
$$= 22.8\ V \text{ B.T.U.}$$

The heat H required to evaporate w lbs. of water at 125° F.,

$$H = 1027.1\ w$$
$$= 1027.1 \times 5.48\ V$$
$$= 5628.1\ V.$$

The weight of dry air, w, entering the condenser is

$$w = \frac{28.78}{29.92} \times 73.55V = 70.8V.$$

The heat H' required to raise the temperature of w' pounds of dry air from 80° to 125° is

$$\begin{aligned} H' &= 0.24\ w\ (125 - 80) \\ &= 0.24 \times 70.8\ V \times 45 \\ &= 764.6\ V. \end{aligned}$$

The total H_t absorbed by the entering air and spray is

$$\begin{aligned} H_t &= H_0 + H + H' \\ &= 22.8\ V + 5628.1 + 764.6\ V \\ &= 6410.5\ V. \end{aligned}$$

But this represents also the heat given up by the steam, or

$$6410.5\ V = 1{,}020{,}800.$$

From which

$V = 159.6$ thousands of cubic feet of atmospheric air necessary to condense 1000 pounds of steam under the required condition.

The weight of water spray, w, to be injected per hour is

$$\begin{aligned} w &= 5.48V \\ &= 5.48 \times 159.6 \\ &= 874.6 \text{ pounds.} \end{aligned}$$

$\frac{H}{H_1} = \frac{5628.1V}{764.6V} = 7.4$, that is, the water spray absorbs 7.4 more heat than the dry air under the given conditions.

Production of Tungsten in 1910.—*Largest Recorded Production.*—Owing to a stronger demand, the price for tungsten ores was higher in 1910 than 1909, and the production therefore rose. The output as calculated from returns received directly from producers and mill men was the largest so far made in this country —1824 short tons, valued at $832,992. Prospecting and development, which have been proceeding more or less steadily in an increasing ratio for the past seven or eight years, have found new deposits and opened known ones, so that there is now a fairly ready response to market demands. The Boulder County, Colorado, field is still the largest producing section, and the Atolia, California, field is second. The ore mined in Boulder County is ferberite (iron tungstate). The Atolia tungsten ore is scheelite. The Atolia field is much smaller than the Boulder field, and gives a higher yield proportionate to area. Returns of 1221 short tons of ore

carrying 60 per cent. tungsten trioxide have been made by Boulder County buyers and producers.

The production of 1910 is believed to be the largest annual output made by this or any other country to date, but the value is less than that of the output for 1907, which was 1640 short tons, valued at $890,048. Very high prices prevailed during 1907 and tungsten at one time during that year reached a price of $14 per unit (1 per cent. of a ton in tungsten trioxide). During 1910 prices ranged from $6.50 to $8.50 per unit for ore carrying 60 per cent. or more of tungsten trioxide. Leaner ores brought a lower price per unit. A little ore was sold as high as $9 or more per unit to buyers having special needs.

The production of concentrated tungsten ores in the United States since 1900 has been as follows:

PRODUCTION OF TUNGSTEN CONCENTRATES IN THE UNITED STATES, 1900–1910, IN SHORT TONS.

Year.	Quantity.	Value.	Year.	Quantity.	Value.
1900	46	$11,040	1906	928	348,867
1901	179	27,720	1907	1,640	890,048
1902	184	34,040	1908	671	229,955
1903	292	43,639	1909	1,619	614,370
1904	740	184,000	1910	1,824	832,992
1905	803	268,676			

The figures in this table can fairly be compared only since the beginning of 1906, as before that date no effort was made to reduce the ores to a common basis of concentration. Since 1906 the figures have been, as far as possible, made to represent the equivalent of ores carrying 60 per cent. tungsten trioxide, which is the ordinary commercial basis in the United States.

No tungsten ore was produced from other parts of Colorado than the Boulder field, although some efforts have been made to exploit the deposits near Silverton. In California, besides the large production made at Atolia, a small quantity of mixed wolframite and scheelite was mined near Nipton. In Arizona a small quantity of ore was produced from old fields, and efforts at production are being made anew near Oracle. In Washington some output of wolframite and hübnerite was made from three mines in Stevens County near Deer Trail, Deer Park, and Loon Lake, and several companies started work on other deposits in Stevens County. In Nevada a small output was made at Browns, Humboldt County. Considerable development work was done on the hübnerite deposits near Osceola, and a mill was put up for concentrating the ore, but no shipments were made during the year. Discoveries of hübnerite-bearing veins northeast of Osceola, near the Utah line (some of them are said to be in Utah), and at Redlich, Nevada, were reported during the year.

RECENT PROGRESS IN THE CHEMISTRY OF THE TERPENES AND CAMPHORS.

BY

JOSEPH SAMUEL HEPBURN, A.M., M.S.,

Secretary of the Section.

(*Presented at a Stated Meeting of the Section of Physics and Chemistry, held Thursday, December 22, 1910.*)

DURING the last quarter of a century, two great researches in the field of organic chemistry have been carried out in Germany, the one research in the aliphatic series upon carbohydrates, proteins and purin bases by Emil Fischer of the University of Berlin, the other research in the carbocyclic series upon the terpenes and camphors and their related compounds by Otto Wallach, the successor of the immortal Wöhler in the chair of chemistry at the University of Göttingen. Reviews of Fischer's work have recently appeared.[1] It is the purpose of this paper to give a resumé of Wallach's studies of the terpenes, camphors and other hydroaromatic compounds. These studies are embodied in over one hundred and fifty papers, published in the *Berichte der deutschen chemischen Gesellschaft*, Liebig's *Annalen der Chemie*, and the *Nachrichten der königlichen Gesellschaft der Wissenschaften in Göttingen, Mathematisch-physikalische Klasse* and have served as the source of Wallach's recent book "Terpene und Campher"[2] upon which this paper is chiefly based.

The labors of Wallach have not been limited to the terpenes and camphors but have extended to many related compounds, including *inter alia* the addition compounds of the terpenes, amines, pyrazols, alcohols, oxides, ketones, aldehydes, acids (mono- and dicarboxylic, amino, hydroxy, ketonic and halogenated). The work of Wallach was rendered exceed-

[1] Recent Progress in the Chemistry of the Proteins, Bradbury, Journal of the Franklin Institute, 1909, clxviii, 85. Recent Progress in the Chemistry of the Sugars, Hepburn, Journal of the Franklin Institute, 1910, clxx, 85.

[2] Terpene und Campher. Zusammenfassung eiginer Untersuchungen auf dem Gebiet der alicyclischen Kohlenstoffverbindungen von Otto Wallach. Leipzig. Verlag von Viet & Comp, 1909.

ingly difficult by the lack of known compounds which would serve for the separation and identification of the individual terpenes, and by the tendency of the terpenes to become inverted, *i.e.*, to pass into metameric compounds under the influence of acids, alkalies, and heat. However, addition compounds of the terpenes were discovered which were suitable for the identification of the individual hydrocarbons, and the inversions of the terpenes were also investigated. The structure of the molecule was determined for the terpenes and their related compounds. Thus the difficulties were overcome and order was brought out of chaos.

The compounds which possess the empirical formula C_5H_8 fall into several classes:

C_5H_8—Hemiterpenes;

$C_{10}H_{16}$—Terpenes (True Terpenes);

$C_{15}H_{24}$—Sesquiterpenes;

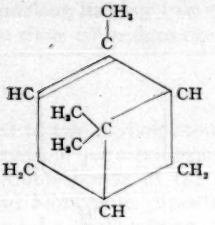
$(C_{10}H_{16})_x$—Polyterpenes (Di-, Tri- and Tetraterpenes).

Isoprene is a hemiterpene, obtained by the destructive distillation of caoutchouc; it is methyl divinyl:

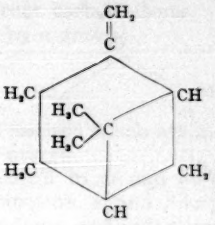
$$CH_2=\overset{CH_3}{\overset{|}{C}}-CH=CH_2.$$

THE TERPENES.

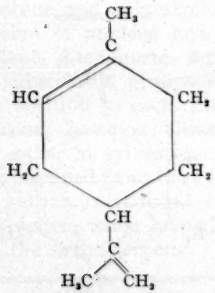
The terpenes are hydro-aromatic hydrocarbons, closely related to cymol (methylisopropylbenzol). Every terpene contains a hydrogenated benzol nucleus and either a methyl and an isopropyl group, or radicals derived from these groups. The general formula of the terpenes is $C_{10}H_{16}$; their isomerism is dependent upon the position of double bonds and of the alkyl groups, and upon intracyclic bonds and intracyclic rings or bridges. The double or ethlyene bond may occur in the nucleus, in the side chain, or at the junction of the nucleus and the side chain. A double bond uniting nucleus and side chain is termed a semicyclic ethylene bond, and the compound, in which it occurs, is called a methene compound. Since two alkyl groups have been substituted in the nucleus of a terpene, it follows that these groups may be in either the ortho, meta or para position to each other. Certain terpenes contain an intracyclic bond which extends across



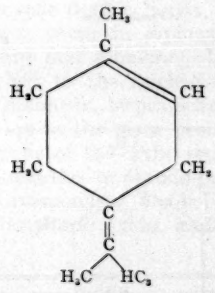
α-Pinene



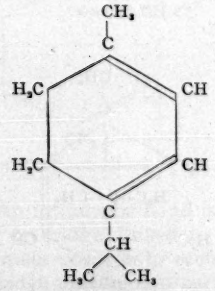
β-Pinene



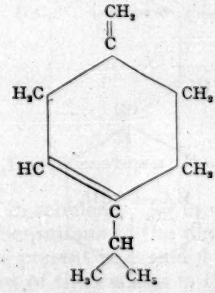
Limonene and Dipentene



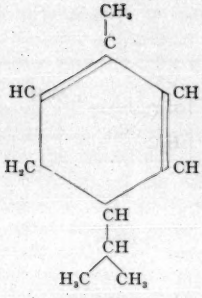
Terpinolene



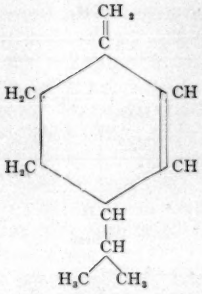
α-Terpinene



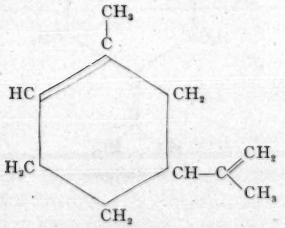
β-Terpinene



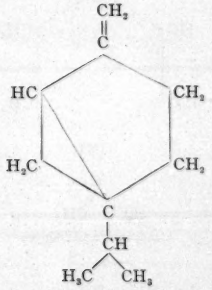
α-Phellandrene



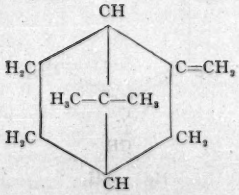
β-Phellandrene



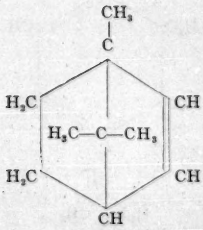
Sylvestrene



Sabinene



D-l-Fenchene

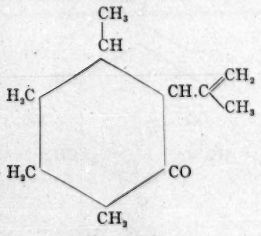


Camphene

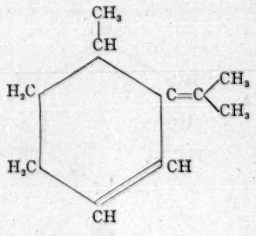
the nucleus linking two non-adjacent carbon atoms. Intracyclic rings or bridges are formed by a group

linked to two carbon atoms of the nucleus which are in either the meta or para position to each other.

Double bonds in the nucleus occur in *d*- and *l*-*a*-pinene, *d*- and *l*-limonene, dipentene, terpinolene, *a*- and *β*-terpinene, *d*- and *l*-*a*-phellandrene, *β*-phellandrene and sylvestrene; in fact *a*-terpinene and *a*-phellandrene are true dihydrocymols. Double bonds in the side chain are found in *d*- and *l*-limonene, dipentene and sylvestrene. Semicyclic double bonds, at the junction of nucleus and side chain, occur in *β*-pinene, terpinolene, *β*-terpinene, *β*-phellandrene and sabinene. Usually the substituent groups are attached to the nucleus in the para position to each other, *e.g.*, limonene, terpinolene, phellandrene; however, these groups are in the meta position to each other in sylvestrene. A terpene of the ortho series has been obtained from the cyclic ketone ortho- or pseudo-pulegon; the ketone is reduced to the corresponding alcohol which loses water, when heated with phosphoric oxide, and passes into the ortho-terpene.



Ortho- or Pseudopulegon



Ortho-Terpene

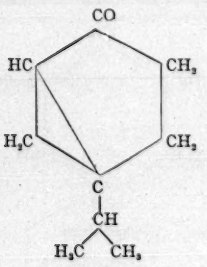
An intracyclic bond is present in sabinene. An intracyclic ring or bridge, linked to two carbon atoms of the nucleus in the meta position to each other, is present in *a*- and *β*-pinene. A bridge uniting two carbon atoms of the nucleus in the para position to each other is found in fenchene and camphene.

The terpenes may be divided into three classes, natural terpenes, terpenes obtained by inversion of natural terpenes, and synthetic terpenes. The natural terpenes occur in various essential oils; Table I enumerates the natural terpenes and certain oils in which they occur.

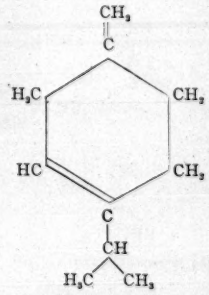
TABLE I.

Terpene.	Essential Oil.
d-α-Pinene	American Turpentine Oil.
l-α-Pinene	French Turpentine Oil.
β-Pinene	Turpentine Oil.
d-Limonene	Oil of Lemon.
l-Limonene	Oil of Pinus Silvestris.
dl-Limonene (Dipentene)	Swedish and Russian Turpentine Oil, Camphor Oil.
α-Terpinene	Ceylon Cardamom Oil.
d-α-Phellandrene	Oil of Bitter Fennel.
l-α-Phellandrene	Oil of Eucalyptus Amygdalina.
β-Phellandrene	Oil of Water Fennel.
Sabinene	Ceylon Cardamom Oil.
Sylvestrene	Swedish and Russian Turpentine Oil.

Terpinolene is a terpene, obtained by inverting pinene by means of sulphuric acid. β-Terpinene is a synthetic terpene built up from sabina ketone. Sabina ketone $C_9H_{14}O$



Sabinaketone

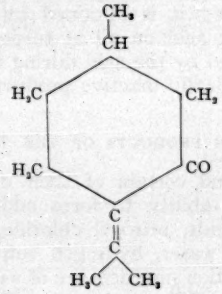


β-Terpinene

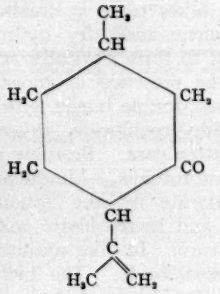
reacts with bromacetic ester, in the presence of zinc, to form an unsaturated acid $C_9H_{14}:CH.COOH$, which loses carbon dioxide to form β-terpinene, $C_{10}H_{16}$.

INVERSION.

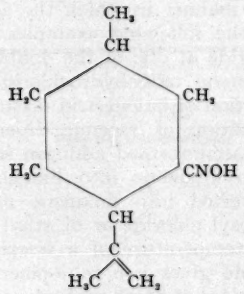
Inversion is the term used to designate the phenomenon in which terpenes and their derivatives pass into isomeric compounds; the change depends on the rearrangement of the atoms in the molecule and a shifting of linkages. Inversion



Pulegon



Isopulegon



Isopulegon Oxime

is produced by the action of acids or alkalies or by exposure to a somewhat elevated temperature. Thus under the influence of alcoholic-sulphuric acid, *a*-pinene and dipentene give rise to *a*-terpinene. At a temperature of 250–270°C., *a*-pinene

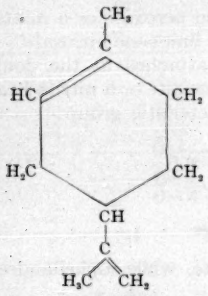
passes into dipentene. When the cyclic ketone pulegon is digested with an excess of hydroxylamine in the presence of much free alkali, the oxime of isopulegon is obtained; the alkali inverts pulegon into isopulegon, by shifting the semicyclic double bond into the side chain, during the formation of the oxime.

Terebene[3] of the Pharmacopœia consists of dipentene and other hydrocarbons; it is obtained by the action of concentrated sulphuric acid on oil of turpentine, the pinene of the latter is inverted by the acid during the process of manufacture and an optically inactive product is formed.

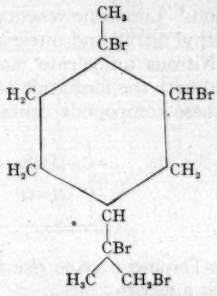
ADDITION PRODUCTS OF THE TERPENES.

The terpenes and certain of their derivatives are characterized by their ability to form addition products with halogens, haloid acids, nitrosyl chloride, nitrous anhydride, nitrogen peroxide, water, hydrogen sulphide and hydroxylamine. These addition products are of value in the separation and identification of the terpenes. The addition usually occurs at the double bonds, although it may also take place with an opening of intracyclic bonds or intracyclic bridges. The manner in which the addition takes place is illustrated by the following examples. Limonene adds dry hydrogen chloride at one of the double bonds to form optically active limonene monohydrochloride; in the presence of moisture, addition of haloid acid occurs at both double bonds with the formation of racemic dipentene dihydrochloride, inversion has accompanied addition in the latter case. Bromine converts limonene into limonene tetrabromide. Limonene is converted into limonene nitrosochloride by the action of nitrosyl chloride or of ethyl nitrite and hydrochloric acid at the temperature of a freezing mixture. In like manner *a*-pinene gives rise to *a*-pinene nitrosochloride. The nitrosochlorides of limonene and *a*-pinene differ in crystal form; upon this fact Chace has recently based a microchemical method for the detection of the presence of oil of turpentine in oil of

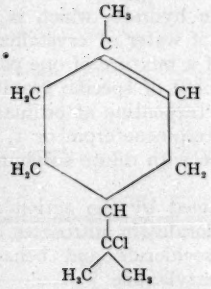
[3] Pharmacopœia of the United States of America, Eighth Decennial Revision, 450.



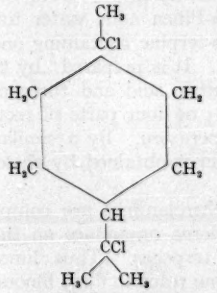
Limonene



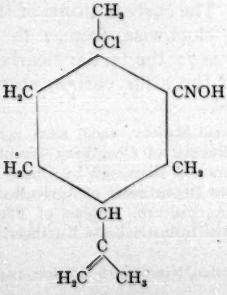
Limonene Tetrabromide



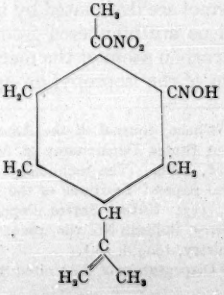
Limonene Monohydrochloride



Dipentene Dihydrochloride



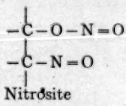
Limonene Nitrosochloride



Limonene Nitrosate

lemon.[4] Limonene reacts with nitrogen peroxide or a mixture of ethyl nitrite and nitric acid to form limonene nitrosate.

Nitrous anhydride may become attached at the double bond with the formation of either a nitrosite or a nitrite; each of these compounds contains a characteristic group:



a-Terpinene gives rise to a nitrosite, while *a*-phellandrene forms a nitrite.

The nitroso group —N=O of the addition compounds frequently is converted into the isonitroso group =N—OH.

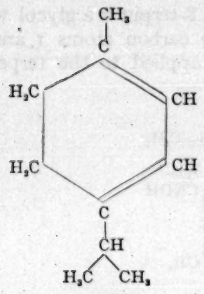
a-Pinen adds water to form terpin hydrate, which is 1, 8-cis-terpine containing one molecule of water of crystallization. It is prepared[5] by the action of a mixture of one part of nitric acid and three parts of alcohol of specific gravity 0.863 on four parts of rectified oil of turpentine at ordinary temperature. By a similar reaction, terpineneterpin or 1, 4-terpin is obtained by shaking sabinene with dilute sulphuric acid.

Nitrolamines are compounds obtained by the action of ammonia or amines on the nitrosochlorides or nitrosates of the terpenes. Thus limonene nitrosochloride and benzylamine react to form limonene nitrolbenzylamine.

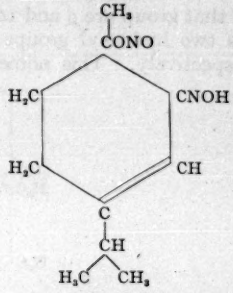
The terms 1, 4-terpin, 1, 8-terpin are based upon a nomenclature in which the carbon atoms of the carbon skeleton of *p*-cymol are designated by numerals. The carbon atoms of the nucleus are numbered from the top, clockwise, from 1 to 6; the carbon atom of the methyl group is 7; the tertiary carbon atom of the isopropyl group is 8, and the other carbon atoms

[4] Chace, Journal of the American Chemical Society, 1908, xxx, 1475; United States Department of Agriculture, Bureau of Chemistry Circular No. 46, 1909. (The technology of oil of lemon is discussed by Chace in several papers: Yearbook of the United States Department of Agriculture, 1908, 333; United States Department of Agriculture, Bureau of Plant Industry, Bulletin No. 160, 1909, 35; Journal of Industrial and Engineering Chemistry, 1909, i, 18.)

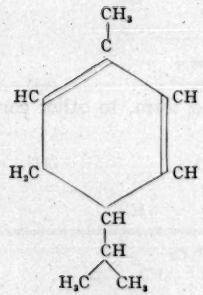
[5] Dispensatory of the United States of America, Nineteenth Edition, 1249.



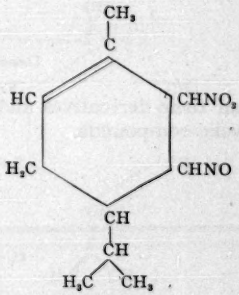
α-Terpinene



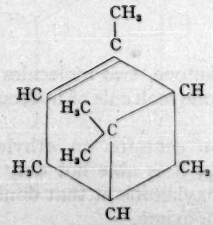
α-Terpinene Nitrosite



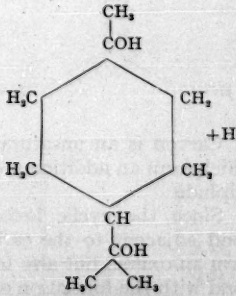
α-Phellandrene



α-Phellandrene Nitrite

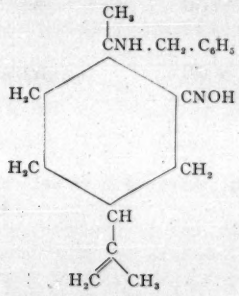


α-Pinene



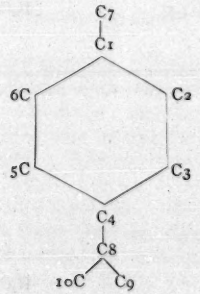
1, 8-Terpin Hydrate

of that group are 9 and 10. Hence, 1, 8-terpin is a glycol with its two hydroxyl groups attached to carbon atoms 1 and 8 respectively. This nomenclature is applied to the terpenes



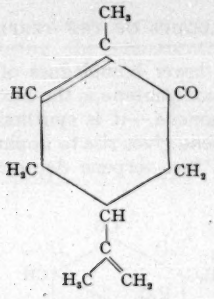
Limonene Nitrolbenzylamine

and their derivatives and, in modified form, to other carbocyclic compounds.

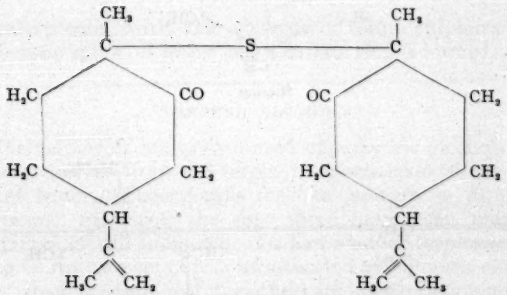


Carvon is an unsaturated cyclic ketone, two molecules of which form an addition product with one molecule of hydrogen sulphide.

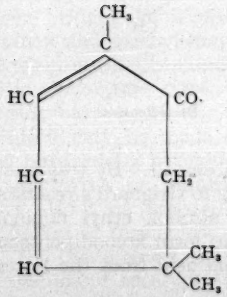
Since the cyclic ketone eucarvon contains an ethylene bond adjacent to the carbonyl group, it is able not only to form an oxime, but also to add hydroxylamine at that double bond with the formation of an oxaminooxime.



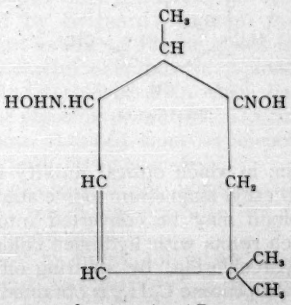
Carvon



Addition Product of Carvon and Hydrogen Sulphide



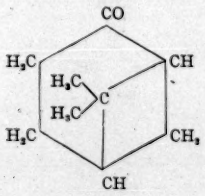
Eucarvon



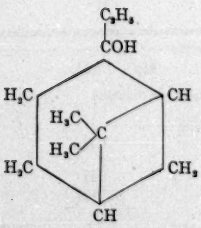
Oxamino-oxime of Eucarvon

HOMOLOGUES OF THE TERPENES.

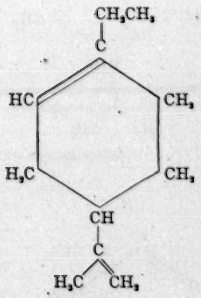
Both higher and lower homologues of the terpenes have been prepared. Homodipentene is the next higher homologue of dipentene,—*dl*-limonene,—it is synthesized from β-pinene. Upon oxidation β-pinene gives rise to nopinon, a cyclic ketone; this ketone was the first terpene derivative, lacking a side



Nopinon



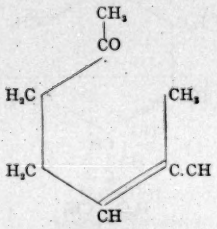
Ethyl Nopinol



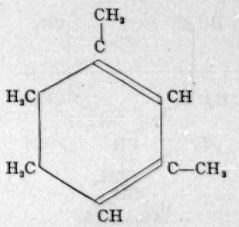
Homodipentene

chain, in which optical activity was observed. By treatment with ethyl magnesium iodide according to Grignard's reaction, nopinon may be converted into an alcohol, ethyl nopinol, which reacts with hydrogen chloride to form homodipentene-dihydrochloride; by splitting off haloid acid from the latter, homodipentene $C_{11}H_{18}$ is obtained.

Dihydro-m-xylol is a lower homologne of the terpenes. It is prepared by heating the unsaturated aliphatic ketone,



Methylheptenon



Dihydro-m-xylol

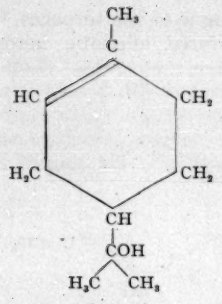
methylheptenon, with zinc chloride or dilute sulphuric acid. The ketone splits off water and a carbon ring is formed.

TERPENE ALCOHOLS.

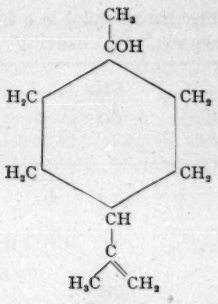
The terpineols are unsaturated monohydric alcohols theoretically derived from 1, 8-terpin by elimination of one molecule of water. Theory calls for four isomers, α-, β-, γ- and δ-terpineol, of which the first three have been prepared; δ-terpineol is still unknown. In like manner terpineneterpin may give rise to a set of four unsaturated monohydric alcohols, one of which is γ-terpineol; the others are known as terpinenol-1, terpinenol-4, and semicyclic terpinenol-4. Methyl nopinol or pinene hydrate is a monohydric alcohol containing an intracyclic bridge; it is prepared by Grignard's reaction from nopinon and methyl magnesium iodide. β-Pinene glycol is a dihydric alcohol obtained by careful oxidation of β-pinene; other glycols are 1, 8-terpin and terpineneterpin which have already been described. Of the glycerols or trihydric alcohols, mention may be made of those obtained from terpinenol-1 and terpinenol-4 by oxidation with permanganate.

Erythrites or tetrahydric alcohols of the terpene series have also been prepared, *e.g.*, terpinolene-erythrite, by the oxidation of terpinolene with permanganate.

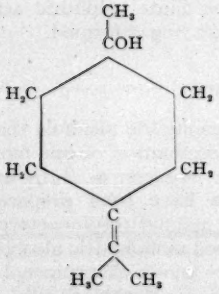
The oxide cineol (1, 8-cineol) or eucalyptol, which occurs in the oils of eucalyptus, cajeput, and wormseed, is the oxide



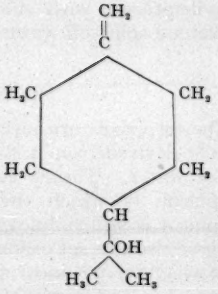
α-Terpineol



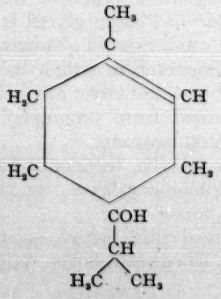
β-Terpineol



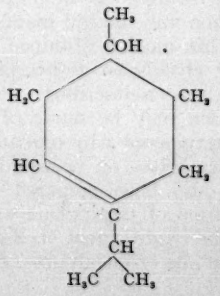
γ-Terpineol



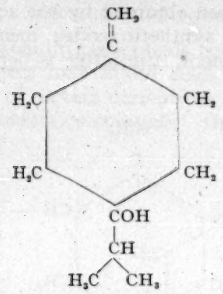
δ-Terpineol



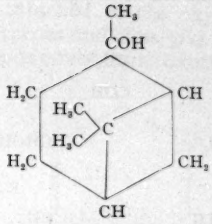
Terpinenol-4



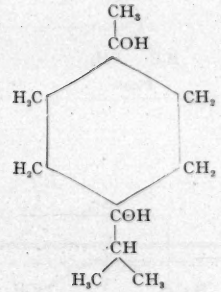
Terpinenol-1



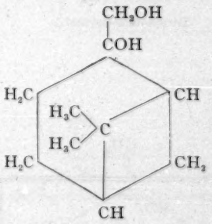
Semicyclic Terpinenol-4



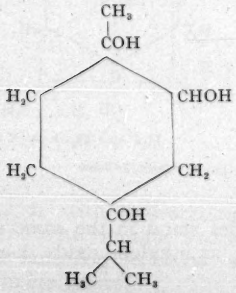
Methyl nopinol



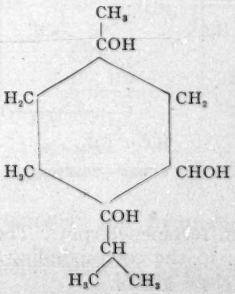
Terpineneterpin—1, 4-Terpin



β-Pinene glycol

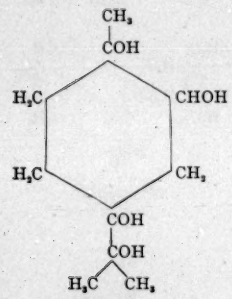


Glycerol from Terpinenol-4

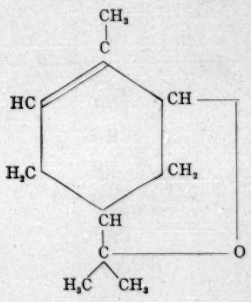


Glycerol from Terpinenol-1

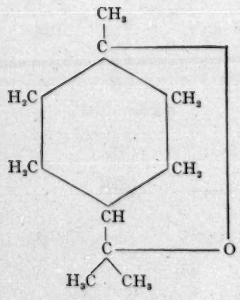
derived from 1, 8-terpin and has been obtained by the action of acids on terpin hydrate. Of the synthetic oxides, mention may be made of pinol and 1, 4-cineol; the latter is derived



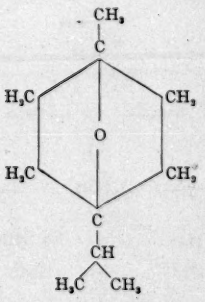
Terpinolene-erythrite



Pinol



1, 8-Cineol—Eucalyptol

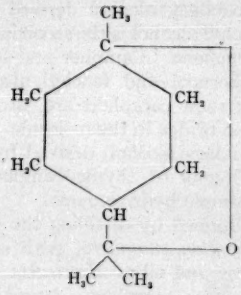


1, 4-Cineol

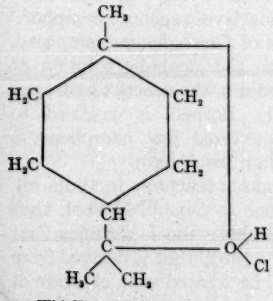
from terpineneterpin. These oxides stand in the same relation to the corresponding glycols, as ethylene oxide does to ethylene glycol.

OXONIUM COMPOUNDS OF THE TERPENE SERIES.

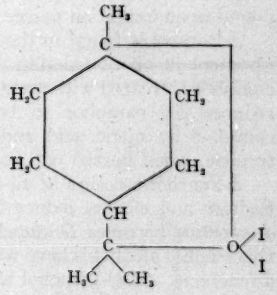
Oxonium compounds contain a tetravalent oxygen atom. Halogens and haloid acids become attached to the oxygen atom of certain derivatives of the terpenes and thus give rise to oxonium compounds. Thus the oxide cineol forms oxonium



1, 8-Cineol



With Hydrochloric Acid



With Iodine

Oxonium Compounds of 1, 8-Cineol

compounds with hydrochloric, hydrobromic and hydriodic acids and with bromine and iodine.

The camphor, fenchone, and bromine react to form an oxonium derivative.

THE CAMPHORS.

The group of camphors includes several alcohols and ketones which are closely related to the terpene hydrocarbons, and have the molecular formula $C_{10}H_{16}O$, $C_{10}H_{18}O$, or $C_{10}H_{20}O$. The generic term camphor is applied to camphor, fenchone, borneol, fenchyl alcohol, menthol, and occasionally to thymol. Borneol is the secondary alcohol derived from the ketone camphor, while fenchyl alcohol is the secondary alcohol derived from the ketone fenchone. Camphor and fenchone have the formula $C_{10}H_{16}O$, borneol and fenchyl alcohol the formula $C_{10}H_{18}O$, all four of these camphors are saturated compounds and contain a carbon bridge in the molecule. Menthol $C_{10}H_{20}O$ is a saturated secondary alcohol, derived from the cyclic ketone menthon. Thymol or thyme camphor is not a true camphor, but is a simple hydroxycymol.

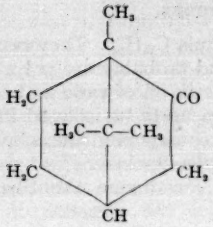
d-Camphor is obtained by distilling the wood of the camphor tree, *Cinnamomum camphora*, with steam; *l*-camphor occurs in oil of tansy and oil of *Matricaria Parthenium*. The manufacture of inactive camphor is based on the following reaction: when oil of turpentine is heated with oxalic acid, oxalate of borneol $C_{10}H_{17}OOC.COOH$ is formed, this compound upon oxidation passes into inactive (racemic) camphor.[6]

d-Borneol is found in the trunk of *Dryobalonops camphora*, *l*-borneol in oil of valerian. When the alcoholic solution of camphor is treated with metallic sodium, the nascent hydrogen reduces the camphor to borneol. Borneol is oxidized to camphor by nitric acid and is converted into camphene, a terpene, when heated with potassium bisulphate.

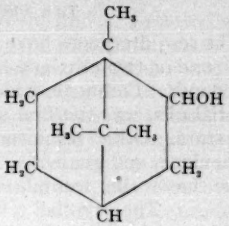
d-Fenchone occurs in oil of fennel, *l*-fenchone in thuja oil. Sodium and alcohol reduce fenchone to fenchyl alcohol, thus *d*-fenchone becomes *D*-*l*-fenchyl alcohol; the *l*- signifies that this fenchyl alcohol is lævo rotatory, the *D* that is derived from *d*-fenchone. If *D*-*l*-fenchyl alcohol be treated with chloride of phosphorus and the mixture be cooled during the reaction, a fenchyl chloride is formed, which loses hydrochloric acid and is converted into *D*-*l*-fenchene, a terpene, when heated with aniline.

Menthol is a saturated cyclic secondary alcohol; it occurs as *l*-menthol in oil of peppermint, which also contains the corresponding cyclic ketone, lævo rotatory menthon.

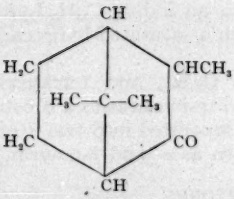
[6] Meyer und Jacobson, Lehrbuch der organischen Chemie, 1902, ii, 1031.



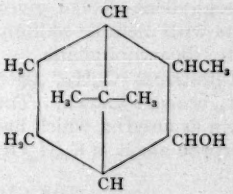
Camphor



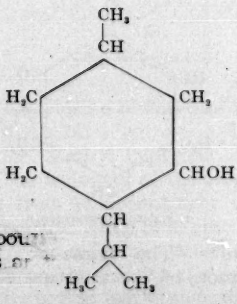
Borneol



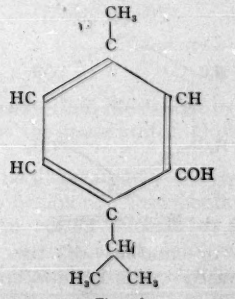
Fenchone



Fenchyl Alcohol



Menthol



Thymol

THE SESQUITERPENES.

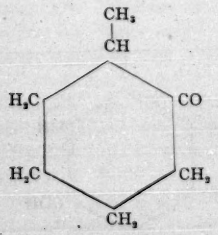
The sesquiterpenes have the formula $C_{15}H_{24}$. They contain either one or two ethylene bonds, and probably are polycyclic compounds. Cadinene, which occurs in oil of cade and other essential oils, was the first sesquiterpene to be isolated in the pure state. Other sesquiterpenes are caryophyllene, clovene, patchoulene, and guajene. Caryophyllene, clovene and patchoulene have the formula $C_{15}H_{24}$, cadinene the formula $C_{15}H_{24}$. The symbol $=$ signifies the presence of one double bond in the molecule; the symbol $=_2$ the presence of two double bonds.

Caryophyllene, which occurs in oil of cloves, adds water to form caryophyllene-alcohol $C_{15}H_{25}OH$. This alcohol is converted into clovene by the action of dehydrating agents. Caryophyllene-alcohol gives rise to an iodide $C_{15}H_{25}I$, which reacts with metallic sodium to form a saturated hydrocarbon, $C_{30}H_{50}$, dicaryophyllane.

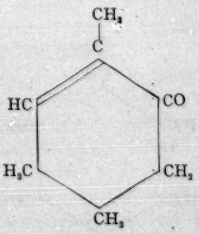
Diterpenes $C_{20}H_{32}$, triterpenes $C_{30}H_{48}$ and tetraterpenes $C_{40}H_{64}$ are also known.[7] Thus elemi resin contains a substance known as amyrin, which has been separated into two isomeric triterpene alcohols $C_{30}H_{49}OH$, known as α- and β-amyrin.

THE CYCLIC KETONES.

The cyclic ketones are hydroaromatic ketones, in which the carbon atom of the carbonyl group forms part of the



1, 2-Methyl cyclohexanon



1, 2-Methyl cyclohexenon

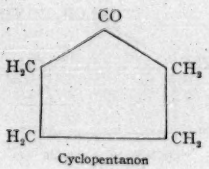
ring or nucleus of the molecule. The names of the saturated cyclic ketones end in -anon, of the unsaturated in

[7] Heusler-Pond, The Chemistry of the Terpenes, 431–435. Blakiston, 1902.

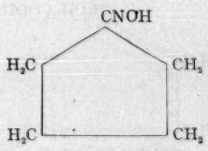
-enon, *e.g.*, 1, 2-methyl cyclohexanon, and 1, 2-methyl cyclohexenon.

In the study of the cyclic ketones, methods have been devised for opening, closing and widening the carbon ring.

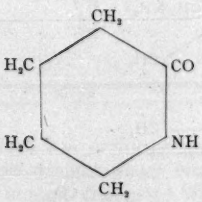
The cyclic ketone, cyclopentanon, forms an oxime, which is converted into an isoxime or lactam by the action of sulphuric acid; the carbocyclic ring of five carbon atoms is converted into a heterocyclic ring of six atoms, five of carbon and one of nitrogen. If the isoxime be boiled with concentrated hydrochloric acid, the ring is opened with the formation of δ-aminovaleric acid, an aliphatic compound.



Cyclopentanon



Cyclopentanon Oxime



Cyclopentanon Isoxime

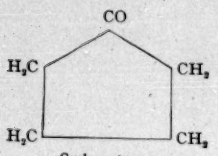
$NH_2CH_2CH_2CH_2CH_2COOH$

δ-Aminovaleric Acid

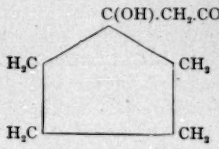
The closing of the ring has already been illustrated by the synthesis of dihydro-m-xylol from the unsaturated aliphatic ketone, methyl heptenon.

The widening of the ring may be illustrated by the transition from cyclopentanon to cyclohexanon. Cyclopentanon, bromacetic ester and zinc react in benzol solution to form cyclopentanolacetic ester, which is converted into cyclopentylacetic acid by the action of hydrobromic acid followed by reduction with zinc dust. This acid forms an amide, cyclopentylacetamide, which undergoes Hofmann's reaction

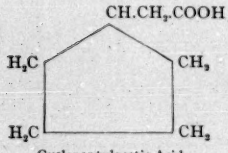
with the formation of an amine, cyclopentylmethylamine. When nitrous acid acts upon this amine, the product is not cyclopentylmethyl alcohol, but cyclohexanol; the carbon



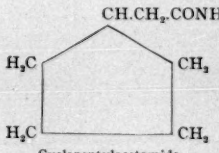
Cyclopentanon



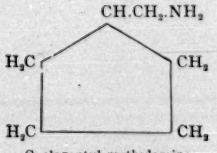
Cyclopentanolacetic Ester



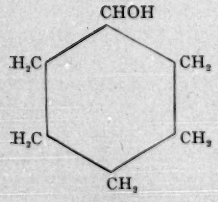
Cyclopentylacetic Acid



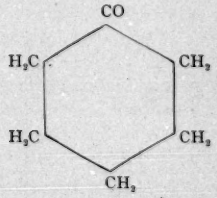
Cyclopentylacetamide



Cyclopentyl-methylamine



Cyclohexanol

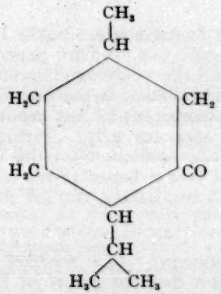


Cyclohexanon

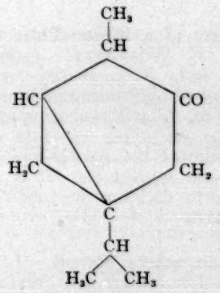
atom of the side chain has entered into the nucleus and a ring of five carbon atoms has been converted into a ring of six carbon atoms. Cyclohexanol may be oxidized to cyclohexa-

non, from which in a similar way may be synthesized cycloheptanon and then, from the latter, cyclooctanon.

Certain cyclic ketones occur in the essential oils. Oil of peppermint contains menthon, oil of pennyroyal pulegon, oil of curled mint carvon, thuja oil α-thujon and oil of tansy β-thujon. Menthon is the ketone corresponding to the cyclic secondary alcohol menthol which has been described under the camphors; α- and β-thujon are physical isomerides. The formulæ of pulegon and carvon have already been given; the formulæ of menthon and thujon follow.



Menthon



Thujon

Wallach has performed a difficult and tedious task. He has made straight many crooked paths and has illumined a field of organic chemistry which is of deep interest to every student of both pure and applied chemistry. His work stands as a classic and he has won for himself a place among the masters of chemical science. It is but fitting and proper that, among the honors that have come to Wallach, is the recent award of the blue ribbon of the world of science, the Nobel Prize for work in chemistry.

Artificial Illumination of a Picture Gallery. (*Elect. Rev. and West. Electn.*, lvii, 519.)—A picture gallery at Hartford, Conn. is illuminated by daylight exclusively by overhead skylights. To avoid suspended fixtures and to imitate the conditions of daylight for artificial illumination, sixty-watt tungsten lamps were employed, on account of the resemblance of their spectrum to that of daylight. They were installed two feet above sheets of special sand-blasted glass and equipped with special deflecting mirrors. The intensity of the light was softened by the frosted glass, and the concentrating mirrors were so arranged as to throw the light mainly on the walls instead of allowing it to waste on the floor. The effect is compared to that of the direct rays of the sun shining through a slight mist, which mitigates the glare without absorbing too much light.

Tests of a Moore-Tube Lighting Installation. E. P. HYDE and J. E. WOODWELL. (*Illum. Eng.*, iii, 615.)—This paper describes tests of the energy consumed and the resulting illumination and flux of light developed in such an installation at the New York postoffice. The illumination varies from about 2.5 to 10.5 candle-ft., and the watts per sq. foot of floor area are 2.85. Particulars are given of the stroboscopic test of the oscillations in the light, which are appreciable. It is suggested that a better result can be secured by dividing the tube system into two halves, run off phases 90° apart.

Radio-active Recoil. L. WERTENSTEIN. (*Le Radium*, vii, 288.)—The author has previously shown that the atoms of Ra B projected by recoil of the α particles from Ra A have a range of about 0.12 mm. in air at atmospheric pressure. Active deposit from Ra Em was deposited on glass and a layer of silver deposited above it. A silver layer 10 $\mu\mu$ thick allowed most of the recoil particles to pass through it, while a layer 20 $\mu\mu$ thick completely stopped them. The range of the recoil Ra B-particle in hydrogen was found to be 0.7 mm. at atmospheric pressure. Experiments on the ionization close to a source of Ra C lead to the conclusion that the recoil Ra D-particles contribute a measurable amount to the initial ionization. Experiments on recoil phenomena in Ra Em, in which Ra A was collected on a positively charged plate, suggested that on the stoppage of Ra A particles in the gas a small percentage of them became negatively charged.

Radium in Great Britain. (*Brit. and Col. Druggist*, 1910, 333.)—According to Sir W. Ramsay the Trenwith mine, in Cornwall, has yielded some 5000 mg. of radium product containing about 10 per cent. of pure radium-bromide. This is the first lot extracted in Great Britain from British ore. Polonium and actinium also exist in the concentrates of the pitch-blende from Cornish mines.

THE RELATION OF CERTAIN NON-LEGUMINOUS PLANTS TO THE NITRATE CONTENT OF SOILS.

BY

T. LYTTLETON LYON, Ph.D., and JAMES A. BIZZELL, Ph.D.,

Cornell University, Ithaca, N. Y.

(*Concluded from Vol. CLXXI, p. 16.*)

SOME RELATIONS BETWEEN SOIL TEMPERATURE AND NITRIFICATION.

Records were kept of the daily soil temperatures taken at 4.30 P.M. on certain unfertilized plats at a depth of six inches during the growing seasons of 1907 and 1908. In Table VIII

TABLE VIII.

AVERAGES OF DAILY SOIL TEMPERATURES AT DEPTH OF SIX INCHES FOR THE PERIODS INTERVENING BETWEEN NITRATE DETERMINATIONS ON CROPPED SOIL.

TIMOTHY, 1907

Plat No.	June 7–13		June 14–20		June 21–July 24	
	Temp. F.	Nitrates, p.p.m.	Temp. F.	Nitrates, p.p.m.	Temp. F.	Nitrates, p.p.m.
711	60.0	4.6	65.3	3.9	68.1	5.3
720	60.5	1.8	66.5	1.2	69.2	2.9

CORN, 1908

Plat No.	June 2–22		June 23–July 6		July 7–28		July 29–Aug. 10	
	Temp. F.	Nitrates, P.P.M.	Temp. F.	Nitrates, p.p.m.	Temp. F.	Nitrates, n.p.m.	Temp. F.	Nitrates, n.p.m.
711	66.8	40.3	69.2	62.0	69.4	182.0	72.2	162.5
720	65.9	31.5	69.8		69.8	211.0	71.1	136.5

the average temperatures for the periods between the dates on which nitrates were determined are stated, also the nitrate content at the end of the period.

In the year 1907 the nitrates were quite constant in amount throughout the season in spite of changes in soil temperature. This is probably on account of the heavy draft of the timothy crop on the soil nitrates. In 1908 the nitrates increase in quantity up to July 28 although the average temperature from July 6 to that date is practically constant. Between July 28 and Aug. 10 there is a very marked rise in temperature in both plats, but it is accompanied by a decrease in nitrates. The temperatures reached in these plats are not high enough to have any depressing effect on nitrification, as has been demonstrated by many experiments. The results merely indicate as in the case of soil moisture, that the nitrifying process is here determined by other factors. The temperature and moisture content of the soil are evidently not the controlling conditions upon which nitrification on these plats depended.

EXPERIMENTS WITH CORN IN WHICH OTHER PLANTS WERE SOWN.

In 1907 and 1908 certain field plats were planted to corn between the rows of which other plants had been sown broadcast. A part of each plat was not planted to corn, but when the other seed was sown between the corn rows it was also sown on the part of the plat on which no corn was planted. In 1907 the corn was in the centre section of the plat and the sections not planted to corn were on the two ends. In 1908 corn was on the end sections and none in the middle. These plats were not on the same soil in 1908 as in 1907. In 1907 the plats were on a sandy soil while in 1908 they were on the clay loam on which the experiments already discussed were conducted. Diagrams I and II show the arrangements of these plats.

The soil samples were taken with a soil auger to the depth of seven inches. Each sample in 1907 was secured as follows:

Six borings were made, carefully mixed on a tablet in the field, placed in a tightly closed jar and carried to the laboratory for moisture and nitrate determinations. In 1908 four borings were made in each end of the plat, the eight borings from the two ends of the same plat were mixed and a portion taken as a sample. Samples from the middles were composed of six borings.

EXPERIMENTS IN 1907.

Corn was planted in hills three feet apart each way. Five kernels were planted in each hill and these were later thinned to three stalks per hill. Millet was sown on certain plats and soy beans on others. These were sown when the corn was cultivated on the dates stated in Table X. Every third plat

DIAGRAM I.

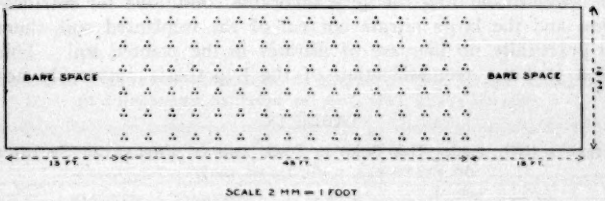
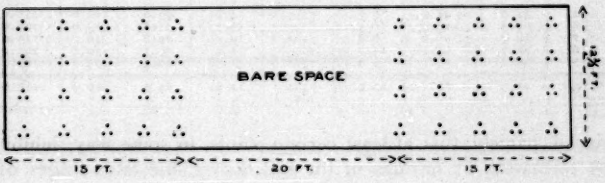


DIAGRAM II.



was a check plat and was planted to corn only, in which the weeds were kept down by cultivation. The unplanted ends received the same cultivation as the remainder of the plat. Nitrates on the planted and unplanted sections are given in Table IX.

The analyses were all made late in the growing season when the growth of corn had reduced the nitrates in the planted sections below that in the bare sections. The nitrate content of the unplanted soil is fairly constant until late in the season, when conditions in September being evidently favorable for the process

of nitrification the analysis of the 16th shows that the nitrates have more than doubled since the analyses of August 25. This may have been due to the abundant rainfall during the early part of September, there having been 2.53 inches between Sept. 1 and 16, while there was only 0.73 inches between Aug. 1 and 31. On Sept. 9 there was a rainfall of 1.06 inches, but although this is a very sandy soil there could have been very little leaching of nitrates judging from the nitrate content on the 16th.

Notwithstanding the very favorable conditions for nitrification and the large nitrate content of the unplanted soil, there is practically no increase of nitrates in the planted soil. This is a striking exemplification of the hypothesis previously advanced, namely, that at least certain plants, in some way, inhibit the formation of nitrates in the soil during the later stages of their growth. It is certainly impossible to account for the failure of the nitrates on the cropped soil to increase by supposing that they were leached out of the top soil, as they would not have remained practically constant while the nitrates on the uncropped soil doubled.

TABLE IX.

NITRATE (NO_3, P.P.M., DRY SOIL) IN CORN AND IN UNPLANTED SECTIONS OF PLATS 1, 4, 7, 10, 13, IN 1907.

Plat No.	August 5		August 19		August 25		September 16	
	Corn	Bare	Corn	Bare	Corn	Bare	Corn.	Bare
1	51.9	90.0	18.6	72.0	14.8	69.6	12.6	130.0
4	49.2	111.0	16.5	84.0	10.5	91.8	15.0	208.0
7	63.0	96.0	8.8	54.0	10.5	79.8	36.0	143.0
10	23.6	73.1	13.7	50.5	31.0	69.3	30.8	165.0
13	18.1	56.1	29.7	78.6	41.5	69.3	55.0	183.1
Average	41.1	85.2	17.5	67.8	22.8	75.9	29.9	165.8

The plats sown to millet and soy beans afford an opportunity to study the effect of these crops on the nitrate content of the soil by comparing the ends of the plats, which, as already explained, were sown either to millet or soy beans alone, with the unplanted ends of contiguous plats. Such a comparison is made in Table X.

There does not seem to be much tendency for the nitrates

to increase under either of these crops during the early stages of growth; yet those crops which were planted after the first analysis was made, thus permitting frequent observation, display something of this tendency. Thus comparing the nitrates under millet sown July 24 on Plat 6 with those in the check Plats 4 and 7 it will be seen that the first determination of nitrates after the millet was up showed an increase in all three plats, but the increase under the millet was 61.6 p.p.m., while that under the checks was 19.2 and 28.2 p.p.m. respectively. The millet sown on Aug. 6 did not make much growth. The decrease in

TABLE X.

NITRATES (NO_3, P.P.M., DRY SOIL) IN MILLET OR SOY BEANS ALONE AND IN UNPLANTED SECTIONS OF ADJACENT PLATS IN 1907.

Date	Plat 5	Plat 4	Plat 6	Plat 7	Plat 8	Plat 10	Plat 9	Plat 11	Plat 13
	Millet,[1] sown June 18	Bare	Millet,[2] sown July 24	Bare	Millet,[3] sown Aug. 6	Bare	Soy beans,[4] sown July 5	Soy beans,[5] sown July 24	Bare
July 9	84.8	98.0	79.0	99.1	100.0	54.4	98.6	53.0	57.5
July 15	72.8	88.4	78.0	81.9	61.7	33.6	60.3	26.4	30.0
July 22	29.9	110.0	113.7	78.4	101.4	84.0	75.6	73.8	81.6
July 29	6.6	91.8	73.4	67.8	79.8	52.2	19.2	54.0	60.0
Aug. 5	2.2	111.0	135.0	96.0	135.0	73.1	8.8	56.6	56.1
Aug. 12	6.5	96.0	81.6	84.0	111.0	62.1	4.0	75.0	78.6
Aug. 19	1.5	84.0	60.0	54.0	84.0	50.5	3.0	55.0	78.6
Aug. 25	2.0	91.8	41.2	79.8	93.6	69.3	2.0	55.0	69.3
Sept. 2	1.0	96.0	25.3	73.8	66.0	87.6	2.0	52.2	90.0
Sept. 16	2.2	208.0	6.0	143.0	45.0	165.0	10.0	145.0	183.1

[1] Yield per acre, 4999 lbs. dry matter.
[2] Yield per acre, 2026 lbs. dry matter.
[3] Yield per acre, 772 lbs. dry matter.
[4] Yield per acre, 3700 lbs. dry matter.
[5] Yield per acre, 894 lbs. dry matter.

nitrates between Analyses of Aug. 12 and 19 under the millet on Plat 8 was 27.0 p.p.m. as against 30.0 and 116.6 p.p.m. on Plats 7 and 10 respectively. Plat 9, on which soy beans were sown July 5, shows about the same nitrate content at each analysis up to July 22 as its checks, Plat 7, and Platt 11. Plat 11, which was sown to soy beans on July 24, continues about the same as its checks until Aug. 12. Neither crop can be said to have been associated with any marked increase in nitrates at any stage of its growth, although the nitrate content of the soil under them does not show, in early growth, the decrease that would be expected. There is the same tendency for nitrates to con-

tinue at a low figure throughout the latter part of the season under millet, as has already been noted under corn. Although Plat 4 shows an increase in nitrates of from 96.0 p.p.m. on Sept. 2 to 208.0 p.p.m. on Sept. 16, Plat 5 shows practically no gain, notwithstanding the fact that the absorption of nitrogen by the millet crop had practically ceased at that time. The millet sowings of July 24 and Aug. 6 show this same phenomena.

Soy beans do not exhibit this property to the same degree.

TABLE XI.

NITRATES (NO_3, P.P.M., DRY SOIL) IN CORN AND IN UNPLANTED SECTIONS OF PLATS 1, 4, 7, 10, 19, 22, 25 IN 1908.

Plat No.	July 22		Aug. 31	
	Corn	Bare	Corn	Bare
1	85.0	65.8	99.0	79.3
4	66.5	60.4	89.9	82.3
7	78.0	64.0	107.1	78.7
10	74.7	69.1	105.4	48.0
19	171.6	102.4	111.6	82.3
22	140.5	143.0	99.2	75.0
25	140.5	100.7	126.0	75.0
Average	108.1	86.5	105.4	74.4

Between the dates mentioned there was a slight increase in nitrates under the sowing of July 5, and a marked increase under the sowing of July 24.

EXPERIMENTS IN 1908.

The plan of experiments in 1908 was primarily the same as that of 1907, but soy beans were not used and there was a difference in the arrangement of the planted and unplanted sections of the plats and the character of the soil, all of which have before been noted. Analyses were made only on July 22 and Aug. 31. Table XI contains a comparison of the planted and unplanted sections of the check plats, all of which received the same treatment.

The higher nitrate content of the planted soil on July 22 is in line with previous results, but a similar relation on Aug. 31 is not, as the nitrate content under corn is usually low at that time. The growth of corn was very poor on these plats, the plants growing only three or four feet high, and producing only about one-third of a crop of fodder. There was, consequently, a very small absorption of nitrogen as compared with a normal crop. It seems likely that the failure of the crop to utilize the available nitrogen resulted in the high nitrate content as late as Aug. 31.

Millet was sown in the corn and in the middles of certain plats as in 1907, but was not sown on different dates. A mis-

TABLE XII.

NITRATES (NO_3, P.P.M., DRY SOIL) IN SECTIONS OF PLATS IN CORN AND MILLET TOGETHER, AND IN CORN AND WEEDS TOGETHER AND IN SECTIONS OF SAME PLATS IN MILLET ALONE AND IN WEEDS ALONE, 1908.

Plat No.	July 22		August 31		
	Corn and millet	Millet	Corn and millet	Millet	
6	76.8	44.1	9.9	4.0	No fertilizer
9	128.0	130.4	13.8	76.5	Nitrate of soda
21	138.8	96.3	45.0	6.0	No fertilizer
24	315.5	258.0	190.0	160.0	Nitrate of soda
	Corn and weeds	Weeds	Corn and weeds	Weeds	
5	84.5	56.3	15.4	7.7	No fertilizer
20	145.2	132.4	12.0	14.0	Nitrate of soda

cellaneous assortment of weed seeds was sown on the ends and middles of other plats. Certain of the plats so treated had an application of nitrate of soda before the corn was planted. Table XII shows the nitrate content of the soil under the corn and millet mixed, the corn and weeds mixed and under millet and weeds alone.

The yields of corn were extremely poor on these plats, being naturally poorer than the check plats that received cultivation.

This is an interesting condition as it gives in some cases about the same yield of corn and millet combined, as of millet alone, and the same for weeds. This is brought out in Table XIII.

On July 22 the nitrates are, in general, higher in the soil planted to the mixture than in the soil planted to a single crop, in spite of the fact that the draft on the available nitrogen must have been nearly the same on both sections. If it is true that the early stages of the plant growth favor nitrification in the soil, and that, as indicated by results already presented, corn is much more effective in this respect than is millet, the higher

TABLE XIII.

YIELDS ON SECTIONS OF PLATS PLANTED TO CORN AND MILLET AND CORN AND WEEDS, AND ON SECTIONS PLANTED TO MILLET AND WEEDS ALONE.

Plat No.	Crop on section	Yield of corn, lbs.	Yield of other crop, lbs.	Total yield on section, lbs.	Yields on sections calculated to same area, lbs.
6	Corn and Millet	3.87	49.63	53.50	35.66
	Millet	....	42.40	42.40	42.40
9	Corn and millet	6.55	42.39	48.94	32.62
	Millet	....	39.43	39.43	39.43
21	Corn and millet	3.45	43.60	47.05	31.36
	Millet	....	34.04	34.04	34.04
24	Corn and Millet	7.91	47.13	55.04	36.68
	Millet	....	36.73	36.73	36.73
5	Corn and weeds	5.85	22.83	28.68	19.12
	Weeds	....	18.54	18.54	18.54
20	Corn and weeds	5.27	23.73	29.00	19.32
	Weeds	....	20.35	20.35	20.35

nitrate content under the mixture of corn and millet than under the millet alone is thus readily accounted for.

This experiment, moreover, eliminates the factor of cultivation, to which the higher nitrate content under corn has usually been ascribed. With the corn plats receiving no more cultivation than the millet plats, and producing practically the same total quantity of dry matter the higher nitrate content of the corn soil must be due to some factor other than cultivation. This again suggests the possibility of a beneficial influence on nitrification, or the utilization of nitrogen in some form other than that of nitrates by the corn plant.

THE EXCESSIVE SUPPLY OF NITRATES IN CORN LAND.

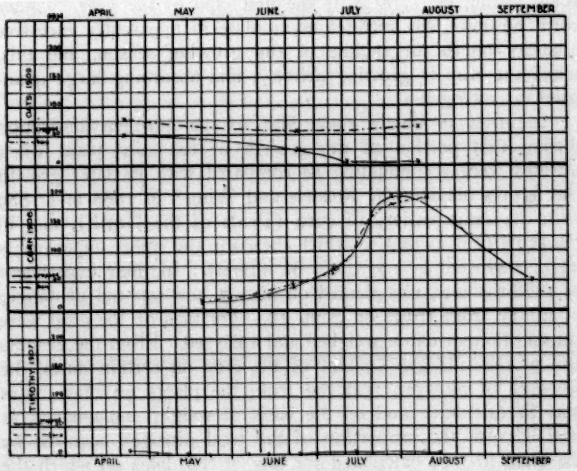
Another significant fact brought out by a study of the nitrates under corn is the great excess of nitrates over the apparent needs of the plant during the first half of the growing season. Under oats and millet there appears to be an increase of nitrates during the very early stages of growth, but this quickly disappears as the growth of the plant proceeds. Under grass there is very little or no accumulation of nitrates at any stage during the growth of the first crop of the year. Under corn, however, the nitrates accumulate in apparently excessive quantity up to the middle of the growing season, and this, while the crop is growing actively, and absorbing large quantities of nitrogen.

In order to obtain some idea of the nitrogen absorption during that portion of the growth of the corn plant when nitrates were accumulating as compared with its later growth the figures obtained by Roberts and Wing[1] in 1888 and 1889 with the same variety of corn (Pride of the North), and in the same field as that in which the corn and millet experiments were conducted in 1907, are of interest. In their experiment of 1888 the corn was planted on May 7, and was out of danger of injury from frosts on Sept. 10. Portions of the crop were cut on different dates, weighed and analyzed. From the weights and protein-nitrogen content of the crop on certain dates, the amounts of nitrogen removed from the plants on these dates may be calculated and on the basis of weight and analysis at final harvest, the proportion of the total nitrogen acquired by the plant may be calculated for any of the dates on which the cuttings were made. Estimated in this way the corn plants had absorbed 43 per cent. of their nitrogen on July 24 and 63 per cent. on Aug. 8. In 1889 the corn was planted on May 12, and was mature Sept. 24. On Aug. 2 it had acquired 53 per cent. of its total nitrogen, on Aug. 17, 50 per cent., and on Aug. 31, 67 per cent. The figures for 1889 are somewhat contradictory as the proportion of nitrogen taken up on Aug. 17 was less than on Aug. 2. The figures indicate that at least 50 per cent. of the nitrogen utilized by "Pride of the North" corn in this

[1] Cornell Experiment Station, Bulletins 4 and 16.

locality in an average year is absorbed by the end of July. Referring to Table III, it will be seen that on July 27, the nitrate content of the soil under the corn on the unfertilized plats was 191 p.p.m., while that on the cultivated soil on which no plants grew was 177 p.p.m. Even as late as Aug. 10, the nitrates under the corn on these plats were 173 p.p.m. and unplanted soil was 185 p.p.m. It is to be expected that there would be a large

DIAGRAM III.



Average nitrate content of soil from eight unfertilized plats during three successive years. A different crop was grown each year and during two years the nitrates are shown on the unplanted sections of the plats. The curves indicate seasonal changes. Nitrates in cropped soil ——. Nitrates in bare soil - - - - - -

accumulation of nitrates in the cultivated and uncropped soil, but why this should be true of the soil carrying a heavy crop of corn, practically one-half of the nitrogen of which had been absorbed, it is difficult to understand. The formation of nitrates during this period must have proceeded with tremendous activity if nitrates were the only source of nitrogen supply for the crop.

Some conditions indicate that corn, at least during part of its period of growth, utilizes nitrogen quite largely in forms

other than nitrates. Ammonification apparently never proceeds more rapidly than nitrification in normal soils, which would bar that form of nitrogen as a very considerable source of supply. Organic nitrogen in some of its soluble forms is the only remaining alternative. The great benefit derived by corn from the application of farm manure, suggests the possible use of nitrogen in this form.

During the later growth of the corn plant there is a great falling off in the nitrate content of the soil under the plants as compared with the unplanted soil. There seems to be no question that nitrates are absorbed by corn in large quantities during the period of growth during which it is securing the second half of its nitrogen supply. (See Diagram III.)

EXPERIMENTS IN 1910.

During the growing season of 1910, determinations of nitrates were made under corn, potatoes and oats. These were from plats planted to each crop, of which two plats were limed and two unlimed. An unplanted strip ran through the centre of each plat. Soil samples were taken on the planted and unplanted sections of each plat. The sections are designated as "north ends," "middles" and "south ends." The "north ends" and "south ends" were both planted; the "middles" grew no crop, but were given the same soil treatment as the remainder of the plat. This consisted in cultivation on the corn and potato plats, and scraping the surface on the oat plats. Soil samples were taken to a depth of four feet on the "north ends" and "middles," but on the "south ends" were taken to a depth of only one foot, except on May 12, when composite samples from the "north ends" and "south ends" were analyzed.

The soil on which these plats were located was a heavy clay loam in the same field as that in which most of these experiments have been conducted. This particular piece of land was not uniform as regards either production of crops or nitrates. Fortunately each crop was grown on four separate plats and, in spite of irregularities in single plats, the average of the four plats in each crop gives quite concordant results.

The weather during the growing season of 1910 was drier than normal, and the early part of the season was unusually cool.

The yields of oats and potatoes were about average size, but the corn crop was extremely poor. The small corn crop was due to the soil rather than to the weather, as no manure had been applied to the land, and this soil does not produce good yields of corn unless it is well manured. It will be noticed from Table XIV that the nitrates under corn run over a hundred parts per million in the surface foot of soil, in spite of which large quantity of soluble nitrogen the crop was extremely poor. Potatoes and oats made a much better growth and reduced the nitrates considerably lower. This is another example of the slight response of corn to nitrates on this soil.

Planting was performed on the following dates: oats (White Russian) on April 28; potatoes (Enterprise) on May 16; corn

TABLE XIV.

AVERAGE NITRATE CONTENT (NO_3 P.P.M.) IN THE SURFACE FOOT OF SOIL OF THE FOUR PLATES PLANTED TO EACH CROP ON THE DATES WHEN ANALYZED.

Crop.	May 12.		June 1.		July 28.		Aug. 17.		Sept. 9.		Oct. 17.	
	Planted.	Not planted.	Planted.	Not planted.	Planted.	Not planted.	Planted.	Not planted.	Planted.	Not planted.	Planted.	Not planted.
Corn	65.8	56.8	98.5	62.3	167.6	92.1	178.8	166.9	247.5	273.3	244.3	166.9
Potatoes	95.1	34.2	121.8	57.8	126.6	145.3	138.6	134.9	99.3	129.7	43.0	145.2
Oats	97.1	48.9	125.1	87.8	74.9	84.5	82.1	154.4	66.9	169.7	96.8	210.6

(Pride of the North) on May 21. The oats were harvested on Aug. 7 and the corn and potatoes Oct. 20.

Table XIV contains a statement of the average nitrate content of the surface foot of soil on the cropped and uncropped sections of the four plats planted to each crop. For the cropped sections, the averages include both of the cropped ends of the plats.

An examination of Table XIV shows, so far as the corn crop is concerned, the characteristically higher nitrate content in the planted than in the unplanted soil during the latter part of July. The nitrate content of the planted soil was slightly higher than that of the planted before the crop was seeded, and nitrates continued to develop more rapidly under the corn up to the latter

part of July. From that time until the corn was mature in September, the nitrates under the crop decreased as compared with the unplanted soil in the usual manner, but the analysis of Oct. 17 shows a greater relative increase in the planted soil, which is contrary to the hypothesis which has been advanced. It is possible that the very feeble growth of the crop may account for this, as it evidently was the reason for the slight reduction of the nitrates under the crop through the growing season.

Potatoes, which were a normal crop, gave results similar to those obtained from normal yields of corn. The difference in the nitrate content of the potato plats and of the contiguous corn

TABLE XV.

NITRATES IN EACH OF UPPER FOUR FEET OF SOIL.

Crop	Depth.	May 12.		July 28.		Aug. 17.		Sept. 9.		Oct. 17.	
		Ends.	Mid.	N. E.	Mid.	N. E.	Mid.	N. E.	Mid.	N. E.	Mid.
Corn.....	1	65.8	56.8	173.9	92.1	200.8	166.9	236.5	273.3	309.0	166.9
Corn.....	2	33.8	25.1	55.4	47.2	48.8	43.4	78.9	99.6	64.3	57.2
Corn.....	3	24.9	16.6	41.2	25.6	44.0	34.3	46.9	56.2	43.2	32.7
Corn.....	4	21.2	15.0	43.8	30.6	41.8	24.4	44.7	72.1	50.3	40.4
Total		145.7	113.5	314.3	195.5	335.4	269.0	407.0	501.2	466.8	297.2
Potatoes.....	1	95.1	34.2	154.8	145.3	163.8	134.9	110.3	129.7	35.0	145.2
Potatoes.....	2	39.4	18.8	49.9	44.1	62.8	49.2	52.4	59.9	29.3	42.5
Potatoes.....	3	29.7	19.6	37.3	35.1	44.5	37.8	28.5	38.2	24.7	38.2
Potatoes.....	4	30.7	18.3	34.7	31.2	41.8	36.0	28.5	29.3	26.9	36.6
Total		194.9	90.9	276.7	255.7	312.9	257.9	219.7	257.1	115.9	262.5
Oats.....	1	97.1	48.9	106.5	84.5	95.6	154.4	84.0	169.7	152.6	210.6
Oats.....	2	32.3	27.5	37.2	33.4	38.7	47.7	28.0	46.6	51.0	53.4
Oats.....	3	15.6	11.7	21.3	23.5	28.0	35.4	19.8	45.7	26.7	27.8
Oats.....	4	30.8	21.6	21.7	23.2	25.0	30.4	21.7	39.8	27.8	32.7
Total.....		175.8	109.7	186.7	164.6	187.3	267.9	153.5	301.8	258.1	324.5

plats on Oct. 17 is very marked. Although the vines were dead on this date, the nitrates were lower under the plants than at any period during their growth, while nitrification had again gone forward in the unplanted soil.

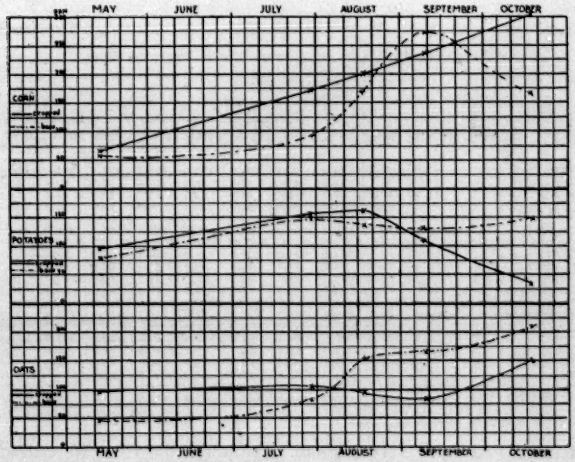
Nitrates under the planted and unplanted sections of the oat plats were of the same relation as in previous years. Nitrates continued to decrease after harvest as shown by the analysis of Sept. 9, one month after harvest. A slight increase is shown by the analysis of Oct. 17, but it will be noted that while nitrates in the planted soil increased 14.7 p.p.m. during that time, the unplanted soil shows an increase of 56.2 p.p.m. in its nitrate content.

NITRATES AT DIFFERENT DEPTHS.

In order to ascertain what effect the upward and downward movement of nitrates may have on the apparent connection between the plant and the nitrate content of the surface soil samples were taken on the "north ends" and "middles" of each plat to a depth of four feet, each foot being analyzed separately. The results of these analyses are shown in Table XV.

The analyses show that nitrates are found to a depth of four

DIAGRAM IV.



Average nitrate content of soil from planted and unplanted sections of four plats of corn, potatoes and oats in 1910. Nitrates in cropped soil ——. Nitrates in bare soil - - - - - - - -

feet, but that the changes in nitrate content of the soil are not great beneath the first foot. Where changes occur in the second foot, they usually accompany corresponding changes in the surface foot. An increase in the nitrates in the surface foot is seldom accompanied by a decrease in the second foot, as would be the case if the augmented nitrate content of the upper foot were due to an upward movement of the nitrates. On the other

hand, the two upper feet increase or decrease in nitrates on the same dates, indicating a downward movement of the nitrates. It would appear from these figures that the nitrate content of the surface foot is determined, in the main, by the rate of nitrification and by the removal of the nitrates, by various means, from that layer of soil. (See Diagram IV.)

The results of the experiments in 1910 are generally in line with the hypotheses we have advanced to account for the characteristic relations of certain non-leguminous plants to the nitrate content of the soil on which they grow. While these characteristic relations, at least in so far as the soils experimented with are concerned, may be considered to be definitely shown for normal crops by these experiments extending over four years, the hypotheses to account for them are still matters for experimentation, which must be based on somewhat different methods from those used heretofore. That the plant exerts an influence in accelerating or retarding nitrification at certain stages of its growth or afterwards, is indicated by these experiments and will constitute a subject for further investigation.

SUMMARY.

The nitrate content of soil under timothy, corn, potatoes, oats, millet, and soy beans was different for each crop when on the same soil. There was a characteristic relationship between the crop and the nitrate content of the soil at different stages of growth. During the most active growing period of the corn crop, nitrates were higher under corn than in cultivated soil bearing no crop. Under a mixture of corn and millet, nitrates at this period were higher than under millet alone, although the crop yields were about the same on both plats.

These phenomena may be accounted for on the assumption that nitrification is stimulated by some processes connected with the active growth and absorbing functions of plants, particularly of corn, although there are indications that the corn plant obtains a part of its nitrogen in some form other than nitrates, the combination of which conditions may account for the very high nitrate content of the soil under corn.

Under both corn and oats, the nitrate content was higher during the period when the crop was making its greatest draft on the

soil nitrogen than in the later stages of growth, in spite of the fact that the nitrates in the uncropped soil were increasing while those in the cropped soil were disappearing. Nitrates under these crops and under millet failed to increase late in the season, when nitrogen absorption had practically ceased, although uncropped soil showed a very large increase in nitrates at that time.

This in conjunction with facts before mentioned, indicates a further influence of the crop on the process of nitrification, and may be accounted for on the supposition that the plants, during their later period of growth, exert, in some manner, a retarding influence on nitrification.

The large differences in the nitrates under the crops mentioned may, aside from the influence of cultivation, possibly be found in the inherent differences between plants of different species in their stimulating or inhibiting influence on nitrification, as well as in their relative rates and amounts of nitrogen absorption.

Changes in the moisture content, or in the temperature of soil under crops during the growing season, had no important effect on the nitrate content of the soil, except under the legume, soy beans. On uncropped soil an increase in moisture content in September was accompanied by a marked increase in nitrates.

Preparation of Argon. G. CLAUDE. (*Comptes rendus*, cli, 752.)—Oxygen obtained in the liquefaction of air is a suitable material for the rapid preparation of argon. This liquid practically contains over 95 per cent. of oxygen, and its chief impurity is argon, the volatility of which is intermediate to that of oxygen and nitrogen. Thus 96 per cent. oxygen contains normally more than 3 per cent. of argon. To separate this the oxygen may be absorbed by copper and the nitrogen by magnesium. The gas is passed through a copper tube heated to a dull redness. The tube is charged with 2.5 kilos of reduced copper mixed with a little copper turnings to increase its absorptive capacity. From this tube the gas passes through an iron tube containing magnesium powder and red hot, and finally through a heated silicon tube containing copper oxide to absorb any hydrogen derived from the moisture in the copper or the oxygen. By this means 3 litres of gaseous oxygen may be treated per minute and from 4 to 6 litres of argon be obtained per hour. About 8 to 12 litres of argon are obtained before the copper becomes spent. This can be regenerated by hydrogen in about one and a half hours.

FRANKLIN INSTITUTE

REPORT OF THE BOARD OF MANAGERS FOR THE YEAR ENDING SEPTEMBER 30, 1910, WITH APPENDICES EMBRACING THE ANNUAL REPORTS OF THE VARIOUS COMMITTEES AND SECTIONS.

To The Members of the Franklin Institute:

For my re-election to the honorable position of President of Franklin Institute, I thank the membership of the Institute present and absent.

As I have told you before, no part of the very varied work in which I am engaged, gives me more pleasure or has a greater hold upon my interest, than the work of the Franklin Institute.

The past year has seen a material advance in the affairs of the Institute and a material improvement in methods and results. This is due, in part, to an awakened interest in the Institute, and in very large part, to the ability and activity of the secretary, Dr. R. B. Owens, who has joined the force since our last annual meeting.

The work of the standing committees has been improved, and notably that of the Committee on Science and the Arts has been greatly simplified; all as set out in the reports of the committees submitted herewith. These reports bring the record down to September 30, 1910:

We enter now a new year with a permanent secretary,—this for the first time since the resignation of the lamented Dr. Wahl, who was for many years the efficient and self-sacrificing secretary of the Institute. The prospect of future good work was never brighter in the history of the Institute.

The Library is becoming of more and more use to the public; the Schools are more and more attracting the attention of the industrial population of Philadelphia and the classes are gaining in numbers. The work of the Committee on Science and the Arts has proven more and more attractive to men of reputation and ability.

Our finances are still in an unsatisfactory condition, but unsatisfactory as it is, it is an improving condition. The Franklin Fund slowly grows and your Board of Managers have great hope that in a relatively short time we can fix a date for the beginning of the new building, which everyone has very much at heart. We have been disappointed from year to year at not being able to say more definitely that the new building was assured; we have not been disheartened, and while our new building fund has been slowly growing, we have increased our efforts to improve and extend the work that has been carried on in this historic building. When or whether a more commodious and suitable home for Franklin Institute is obtained,

the work will not be permitted to lag, and the effort to prove worthy of our honored predecessors, and to set a noteworthy example for the emulation of our successors, will never be relaxed.

For the Board of Managers,

WALTON CLARK,
President.

PHILADELPHIA, January 18, 1911.

REPORT OF THE COMMITTEE ON INSTRUCTION.

To the Board of Managers:

The Committee on Instruction has pleasure in submitting the following report of its work during the year ending September 30, 1910.

After numerous Committee meetings held during the spring and summer months, the entire curriculum of the school was reorganized and the title formerly known as the "Night Schools," was changed to the "Franklin Institute School of Mechanic Arts." Mr. William H. Thorne was appointed Director, and the following officers of instruction were appointed to assist him in the various departments:

H. P. Tyson, Professor of Mathematics; M. H. Keill, Professor of Naval Architecture; Clement Remington, I. P. Pedrick, A. V. McConnell, Frank H. Lobb, W. N. Twining, Instructors in Drawing; John Burt, Instructor in Mechanics; G. T. Sharp, Instructor in Mathematics.

A new, enlarged and comprehensive pamphlet was issued, descriptive of the various reorganized departments of the School and of the several courses in each department.

The following table shows the registration of students in the various departments:

	Winter Term, 1909.	Spring Term, 1910.
Drawing School	98	67
Mathematics	41	18
Theoretical Mechanics	17	..
Strength of Materials	..	13
Machine Design	5	5
Naval Architecture	12	8
	173	111

As compared with the registration for the year 1909, an increase is shown of 2 students in the Spring Term and 33 students in the Winter Term. The first night's registration in 1911, which was the opening night of the Spring Term of the schools, shows 87 students in one department, as against 45 students in the same department on the opening night in January, 1909; so that the prospects are very bright for a large registration for the year 1911.

Owing to the liberality of the Board of Managers, the School rooms have been thoroughly repainted and renovated, and the light and ventilation greatly improved. These changes have been much appreciated by all who have had occasion to use the rooms, and the regular increased attendance of the students and the improved quality of their work, stand as proof of some of the benefits that have accrued from these improvements.

There were popular lectures delivered during the year in the Witherspoon Hall, and on the following dates:

October 15, 1909, "Navigating the Air," Mr. Augustus Post, Secretary Aero Club of America.
November 12, 1909, "Quality of Light," Mr. Paul F. Bauder, Cleveland, Ohio.
December 10, 1909, "Perils of Peace or a Safer America," Wm. H. Tolman, Ph.D., Director of the Museum of Safety and Sanitation, New York.
January 28, 1910, "Road, Administration and Maintenance," Mr. Logan W. Page, Director Office of Public Roads, Washington, D. C.
February 11, 1910, "Recent Methods for the Production of Light," Dr. Robert H. Bradbury, Southern Manual High School, Philadelphia, Pa.
March 14, 1910, "Salvation of Our Trees," Mr. John Davey, Kent, O.

Respectfully submitted,

LAWRENCE T. PAUL,
Chairman.

REPORT OF THE COMMITTEE ON PUBLICATIONS.

To the Board of Managers:

In response to the new impulses which have reinforced the activities of the Institute in general during the past year, its Publication Department has made marked advances during that period. With the co-operation and, to a notable extent, under the lead of the present Secretary of the Institute, the staff of contributors to the pages of the JOURNAL has been largely increased, so that the literary material at the disposal of your Editorial Committee is now not only more than ample in quantity, but also of such scientific value as to fully maintain the high standing of the Institute in this regard. With this enlarged co-operation, the JOURNAL is gaining renewed recognition as a repository of original data in the domain of the applied sciences and bids fair to become again what it was a generation ago, an exponent of the most important advances in Science and the Arts.

The application of the recently established Potts Gold Medal and also of at least two Longstreth Silver Medals as prizes to be awarded for the most important papers published in the JOURNAL during the year falls in line with the efforts of your Publication Committee in this regard. These papers, hitherto accorded some measure of recognition in the form of special

reprints furnished to their authors by the Institute, have in not a few instances merited a more marked distinction, and this the Institute will hereafter be in position to award.

The improvement of the JOURNAL during the past year as regards its contents has extended to its typographic quality as well. The changes in this direction, while thoroughgoing and extensive, have yet been studiously made to retain that general appearance of the JOURNAL which has characterized it throughout its many years and which has thus, in a way, become a symbol of its stability.

The financial status of the JOURNAL has also improved considerably during the past year. Notwithstanding the additional costs of the publication incurred during this period and, to some extent at least, because of these additions, the income of the publication has overlapped the additional costs and brought it more and more nearly to the point where the cash balance will be that of a surplus instead of a deficit. Even as it is, counting the accretions to the Library, obtained through exchanges with the JOURNAL, its publication affords a substantial gain, though not yet enough to reasonably requite the efforts for its promotion. Not the least important of these efforts are those of the Actuary of the Institute, whose co-operation in the management of the business affairs of the Publication Committee is greatly appreciated by its members.

Respectfully submitted,

LOUIS E. LEVY,
Chairman.

REPORT OF THE COMMITTEE ON SECTIONAL ARRANGEMENTS.

To the Board of Managers:

During the year ending September 30, 1910, thirty-one meetings were held by the Sections and papers on the following subjects were presented:

PHYSICS AND CHEMISTRY SECTION.

Eight Meetings.

October 7, 1909.
Some of the Laws Concerning Voltaic Cells.
Prof. Edward H. Landis.

November 11, 1909.
Advances in Electro-Analysis.
Mr. Jacob S. Goldbaum.

ELECTRICAL SECTION.

Eight Meetings.

October 14, 1909.
Recent Improvements i.. the Design of Nernst Lamps.
Mr. Chas. A. Barton.

November 18, 1909.
The Electric Reduction of Iron Ore.
Dr. Jos. W. Richards.

January 20, 1910.
Promotion of Safety in the Transportation of Explosives and Other Dangerous Articles in the U. S.
Col. B. W. Dunn.

March 3, 1910.
An Analysis of Illumination Requirements in Street Lighting.
Mr. Arthur G. Sweet.

March 10, 1910.
Phenomena of Flocculation and Deflocculation.
Dr. Edward E. Free.

April 7, 1910.
Chemistry of Colloidal Matter.
Dr. Robt. H. Bradbury.

May 5, 1910.
Flax Growing and Linen Manufacturing in the U. S., Present and Future.
Mr. Jas. Wood Pogue.

May 12, 1910.
Recent Progress in the Chemistry of the Sugars.
Mr. Jos. S. Hepburn.

MECHANICAL AND ENGINEERING.

Seven Meetings.

October 21, 1909.
Three Centuries of Glass.
Mr. John I. Arbogast.

December 2, 1909.
The Use of Concrete Piles.
Mr. W. F. Hall.

January 13, 1910.
Methods and Results of Electrical Testing.
Dr. Clayton Sharp.

February 10, 1910.
Electrical Heating.
Mr. W. S. Hadaway, Jr.

February 17, 1910.
Electric Railway Signals.
Mr. Carl P. Nachod.

March 24, 1910.
The Electrometallurgy of Steel.
Dr. Jos. W. Richards.

March 31, 1910.
The Electric Vehicle.
Mr. John Meyer.

April 28, 1910.
Magnetic Hysteresis in a Rotating Field.
Dr. Morton G. Lloyd.

PHOTOGRAPHIC SECTION.

Five Meetings.

October 28, 1909.
Demonstration of the New Bausch and Lomb Balopticon for the Projection of Lantern Slides, Opaque Objects and Micro-Slides.
Mr. Arthur H. Thomas.

December 9, 1909.
Infra-Red and Ultra-Violet—a New Departure in Photography.
Dr. Robt. W. Wood.

December 30, 1909.
Flying, the New Art.
Mr. Wilbur R. Kimball.

January 6, 1910.
Steel in Freight Car Construction.
Mr. C. A. Seley.

February 3, 1910.
Modern Heavy Guns.
Mr. Samuel Lichtman.

March 17, 1910.
A New Pyrometer.
Mr. Chas. E. Foster.

April 21, 1910.
Liquid Gas.
Mr. L. Akesson.

January 27, 1910.
The Making of Lantern Slides.
Mr. Chas. R. Pancoast.

February 24, 1910.
Symposium on Modern Photographic Developers.
Messrs. John Bartlett, Reuben Haines, Alfred Holden, S. Hudson Chapman.

April 14, 1910.
Unusual Trees.
Mr. J. W. Ridpath.
Photomicrographs in Natural Colors.
Dr. Henry Leffmann.

MINING AND METALLURGICAL SECTION.

Three Meetings.

November 4, 1909.
Address of the President of the Section.
Prof. A. E. Outerbridge, Jr.

December 16, 1909.
Comparison of Copper and Lead Smelting.
Mr. Hiram W. Hixon.

May 19, 1910.
Copper Deposits of Franklin-Adams Counties, Pa.
Dr. Edgar T. Wherry.

The attendance at these meetings was much better than during previous years, the average attendance being sixty persons.

It is believed that the subjects presented also proved more interesting than those of previous years. The improvement in attendance and general interest was very marked during the closing months of the year, subsequent to the term embraced in this report.

It is believed that a new stimulus would be given to the work of the sections, if arrangements could be effected to promote co-operative action between the local sections of national scientific and technical associations and the several sections of the Institute, and your committee would suggest that the Board would give authority to the Secretary to use his endeavors towards securing such co-operation.

JAMES CHRISTIE,
Chairman.

PHILADELPHIA, PA., January 11, 1911.

REPORT OF THE COMMITTEE ON LIBRARY.

(Abstract)

To The President and Members of The Franklin Institute:

The Committee on Library begs leave to present the following report of the activities of the Library for the past year:

The following additions were made to the library during the year ended September 30, 1910:

Source.	Bd. Vols.	Unb. Vols.	Pamphlets	Maps.
By Gift	232	251	420	1
By Exchange	23	1	..	..
From JOURNAL	30	29	103	.
Binding	716	..	..	..
Chemical Binding Fund	7	..	..	..
General Appropriation	199	30	3	..
Moore Fund	70	4	..	..
Lea Fund	5	2	..	..
Morris Fund	13	..	50	..
Potts Fund	1	..	..	..

Received in the following monthly installments:

Source.	Bd. Vols.	Unb. Vols.	Pamphlets.	Maps.
1909 October	192	16	42	..
November	58	30	50	..
December	162	22	13	..
1910 January	31	30	11	..
February	84	29	44	..
March	65	17	107	..
April	123	27	102	..
May	55	28	41	..
June	224	27	34	..
July	41	35	25	..
August	124	17	47	..
September	137	39	60	1
	1296	317	576	1

Total additions for the year, 2190.

Gifts of books and pamphlets in large quantities or of special importance were received from Messrs. W. E. Gatchell, R. W. Gilpin, C. J. Reed, E. H. Sanborn, W. R. Webster, Drs. S. Solis Cohen and E. J. Houston, Mrs. J. M. Emanuel, The C. J. Toerring Company and the Royal Technical High School of Karlsruhe. Mr. Carl Hering deposited four volumes.

The contents of the Library on October 1, 1910 (after deducting the books transferred to the Free Library), were as follows:

Volumes bound and unbound	60,904
Pamphlets	47,468
Maps and Charts	2,267
Drawings, Designs, Lithographs	783
Photographs	1,312
Newspaper Clippings	192
Manuscripts	34

Books on deposit, 51.

DUPLICATES.

The following number was added during the year: 111 bound volumes and 300 magazines.

There were sold during the year: 451 bound volumes, 147 unbound volumes, 3 pamphlets, 465 magazines.

BINDING.

The total number of volumes bound during the year was 760, viz.:

Volumes of periodicals	665
Recent volumes of British patents	51
Chemical periodicals charged to the Chemical Periodicals Binding Fund	7
Purchased with the income of the Moore Fund and binding charged to that fund	10
Bound with the income of the Morris Fund	1
Old books rebound	25
Old books repaired	1

EVENING ATTENDANCE.

The Library was open on 44 evenings during the year until 10 o'clock, namely: On the evenings of the Section Meetings and on the monthly meetings of the Institute.

BUILDING CHANGES.

The routine work of the Library has been somewhat disorganized during the past few months by changes in the various parts of the building, which have greatly benefited the Library.

The files of periodicals which have been stored in the Secretary's Office for many years and those which were distributd throughout the school rooms were all transferred to a room in the basement especially fitted up for the purpose.

The two rooms on the first floor which have been in use for book storage for several years were cleaned out. Most of the books and pamphlets were transferred to the old JOURNAL storeroom on the third floor, the stock of JOURNALS which were formerly kept in this room having been transferred to a room in the basement properly arranged as a stockroom.

The Library Committee desires to express its appreciation of the very considerable improvements which have recently been made both in the extension of the space and addition of many conveniences to the Library.

BINDING OF PAMPHLETS.

By arrangement with a friend of the Institute it has become possible to have the pamphlets on mechanics bound and made accessible to readers. After binding they will form a part of the regular Library. A number of volumes are now at the bindery and others are being made ready. They will form a most valuable addition to the literature on mechanics in the Library and it is hoped that it will be possible to obtain funds which will enable the Committee to bind the pamphlets on other subjects.

PUBLIC DOCUMENTS.

Work on the removal to the Free Library of government documents consisting in all of 4666 bound volumes, 132 unbound volumes, and 34 pamphlets, began September 4, 1909, and was continued throughout the year. The collection of old coast survey charts mounted on 249 boards were also included in the transfer. A number of documents on technical subjects were retained; if it is found on examination of the catalogue that they are already in the Library they will be sent to the Free Library later.

ST. ANDREW'S SOCIETY.

The Library had on its shelves books on Scotland, 30 volumes in all, which have not been consulted for many years. At the suggestion of Mr. Ronaldson, a member of the Committee, they have been deposited with the St. Andrew's Society of Philadelphia and will form a part of the library on Scotland which has recently been established, though the Franklin Institute will still continue to own them.

NEW BOOKS.

At the suggestion of the Secretary the new books purchased from month to month will be displayed in the centre of the reading room where they will be accessible to members without any further formality.

For nearly a year an advertisement has appeared in the JOURNAL from month to month calling attention to the fact that the library staff is prepared to verify references and do copying. No requests have yet been made for this service. The notice is still being continued.

Respectfully submitted,

GEO. F. STRADLING,
Chairman, Committee on Library.

REPORT OF THE COMMITTEE ON MEETINGS.

To the President and Members of the Franklin Institute:

Under arrangements made by the Committee on Meetings, with the assistance and co-operation of the Secretary's Office, ten Stated Meetings of the Institute were held during the past year, at which the following subjects were presented:

October Meeting, 1909: "Some of The Lighting Features of The Hudson-Fulton Celebration," by Mr. Arthur Williams.

November Meeting, 1909: "Bakelite and Its Applications," by Dr. Leo H. Baekeland.

December Meeting, 1909: "High-Power Rifle," by Major Franklin Philips.

January Meeting, 1910: "The Dynatak," by Dr. N. M. Hopkins.

February Meeting, 1910: "Development of the Mallet Locomotive," by Mr. Grafton Greenough.

March Meeting, 1910: "The Physical Production of Light," by Dr. Edward P. Hyde.

April Meeting, 1910: "The Waste of Life and Resources in the Mining Industry," by Dr. J. A. Holmes.

May Meeting, 1910: "Some Facts About Electrical Insulation," by Prof. A. J. Rowland.

June Meeting, 1910: "History and Development of Picture Projection," by Mr. F. H. Stewart and Mr. Max Milligan.

September Meeting, 1910: "The Moore Light," by Mr. D. McFarlan Moore.

The attendance at the meetings still continues to grow.

Over two hundred persons attended the June meeting.

This growing appreciation of the standing of the speakers and the value of their addresses is gratifying.

Respectfully submitted,

JAMES S. ROGERS,
Chairman.

January 11, 1911.

REPORT OF THE COMMITTEE ON SCIENCE AND THE ARTS.

To the President and Members of the Franklin Institute:

The Committee on Science and the Arts beg to submit the following statement of its operation for the year ending September 30, 1910:

The total number of cases on the records September 30, 1909, was 72; cases added during the year, 16; cases closed, 30; cases pending September 30, 1910, 58. Amendments relating to the recently adopted regulations were considered at various intervals and have been adopted in their final form. Notable among them is the resolution defining the duty of the sub-committee on Literature to examine papers of unusual merit presented in the JOURNAL with a view to recommending the award of the Potts Medal.

A considerable number of pending cases on which no information was available were, at the suggestion of the Committee on Preliminary Examination, dismissed without prejudice.

The Chairman desires to express his deep appreciation of the active and efficient co-operation of his fellow members of the Committee.

Respectfully submitted,

THOMAS SPENCER,
Chairman.

January 11, 1911.

APPENDIX.

DETAILS OF AWARDS, ETC.

AWARDS OF THE ELLIOTT CRESSON MEDAL.

2432.—Lumiere Color Photography.
2473.—Underwood Typewriter.

AWARD OF THE JOHN SCOTT LEGACY PREMIUMS AND MEDAL.

2457.—Telelectric Company's Piano Player.
2487.—Baekeland's Bakelite.

AWARD OF THE EDWARD LONGSTRETH MEDAL OF MERIT.

2464.—Rushton Trailing Truck for Locomotives.
2465.—Reese Dirigible Balloon.
2463.—Murray's Safety Devices and Protective Appliances for Interior Electric Wiring.

AWARD OF A CERTIFICATE OF MERIT.

2462.—Blanton's Shaft Coupling, Shaft and Hub Connections.

REPORTS MADE ADVISORY.

2442, 2450, 2456, 2468.

CASES STRICKEN OFF THROUGH INSUFFICIENT DATA, ETC.

2243	2270	2275	2288	2290
2356	2390	2398	2414	2415
2434	2438	2444	2451	2452

CASES WITHDRAWN.

2291 2396 2443

PRESENTATION OF ELLIOTT CRESSON MEDAL

TO

JOHN FRITZ, ESQ.

The award by the Franklin Institute of the Elliott Cresson Gold Medal to John Fritz was signalized by its presentation to the venerable ironmaster and inventor on the occasion of a dinner given in his honor by the Manufacturers Club of Philadelphia on Thursday evening, November 17th, ult. The function of making the presentation had been delegated by President Clark of the Institute to former President John Birkinbine, who prefaced his address to the recipient of the medal by a brief review of the tremendous advances which had been made in every direction of human activity during the 88 years of John Fritz's life time, and proceeded to dwell upon the part taken by him in furthering these advances through his work in the development of the iron and steel industries.

In response, Mr. Fritz, reading from manuscript said, in part:

"I appreciate fully this kindly manifestation of your esteem. It gives rise to feelings of emotion, which carry me back to my youth when I was working on the farm from daylight until dark, barefooted, as was the custom at that time, driving the cattle into the yard, milking the cows, feeding or working the oxen. . . . Whatever little I may have accomplished is largely due to the brave and loyal men who so nobly stood by me throughout all the trials and perplexities encountered during my long connection with the iron and steel industries. But, alas, the majority of these loyal associates are gone and the grave has closed over them. Yet they are not forgotten and they shall ever have a green spot in my memory. . . . Much of my success may be attributed to the wonderful progress that has been made in the arts and sciences within this most remarkable century. Having inherited some mechanical ability and being of an investigating turn of mind and disposed to lead rather than to follow, and being possessed of the faculty of drawing able men around me, which is essential at all times to success and more especially at that period, it seemed, in a measure, that I should blend the old and the new. . . .

"While we have properly received great credit for unprecedented developments we have made in the iron and steel industry in the United States, we should not forget that it was the inventions of Cort, of Mushet, of Bessemer, of Siemens, and Thomas that enabled us to accomplish such important results, and to them all civilized nations owe a debt of gratitude for the incomparable blessings their inventions have conferred on society. . . .

"Yet, how few of us, even for a moment, think of the trials, troubles, disappointments, mental anxiety and bodily toil these men underwent in the introduction and perfection of their inventions, besides suffering the sneers and jibes of those who imagined that an inventor was nothing but a wild enthusiast, and treated him accordingly. The story of many inventors is truly pathetic—and none more so than that of the lamented Thomas. The

personal side of the story of the inventor of the basic process can only be appreciated by the reading of his life.

"It is largely to the invention, introduction and perfection of the modern system of steel making in this country that we are indebted for the education of our people in science and in the mechanical and metallurgical arts, which have enabled them to erect such manufacturing plants as were necessary to supply our Government with the sinews of war, making it possible to achieve those glorious victories which at once placed us in the front rank among the nations of the earth."

FRANKLIN INSTITUTE.

(Proceedings of the Stated Meeting, held Wednesday, January 18, 1911.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 18, 1911.

PRESIDENT WALTON CLARK *in the Chair.*

The annual meeting of the Institute was held this evening at eight o'clock, President Walton Clark in the Chair. The minutes of the special meeting of December 9th and the regular meeting of December 21st were read and approved.

The Tellers, Messrs. Griggs, Colvin and Jennings, submitted the report of the ballots cast for officers and members of the Board of Managers. The following persons were duly declared elected to the respective offices:

President (to serve one year), Walton Clark.

Vice-President (to serve three years), James Christie.

Treasurer (to serve one year), Cyrus Borgner

Managers (to serve three years), John Birkinbine, Walton Forstall, E. Goldsmith, Louis E. Levy, Richard Waln Meirs, Alex. P. Robinson, Coleman Sellers, Jr.

Managers (to serve one year), George A. Hoadley, G. E. Kirkpatrick, Isaac Norris, Jr.

The President presented a statement of the work of the Institute during the past year. Mr. Churchill Hungerford, Filtration Engineer, of Philadelphia, presented a communication on "Water Filtration for Industrial Purposes." The speaker described modern methods of filtration and the plants in operation at various large industrial establishments. The progress made in methods of filtration during the past few years was referred to and the types of filters were shown. The subject was illustrated by a number of lantern slides.

At the close of the paper a vote of thanks was presented to Mr. Hungerford.

On motion the paper was referred to the Committee on Publication.

Adjourned.

R. B. OWENS,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, January 4, 1911.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 4, 1911.

MR. THOMAS SPENCER *in the Chair.*

The following reports were presented for final action:

No. 2474.—Baylis Brush Holder. Certificate of Merit. Adopted.
No. 2476.—Roper Safety Propeller. Laid over until next meeting for further information.
No. 2489.—Hopkins' Speedometer and Dynamometer. On motion referred back to Sub-Committee for further information.

The following report was presented for first reading:

No. 2492.—Ramsden's Devices for Raising Vessels when sunk (Advisory) Adopted.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Physics and Chemistry.—The stated meeting of the Section was held in the Hall of the Institute on Thursday, December 22, 1910, at 8 P.M. with Mr. Alfred Rigling in the Chair. Twenty-five members and visitors were present.

An original paper entitled "The Relation of Certain Non-leguminous Plants to the Nitrate Content of Soil," by Professors T. Lyttleton Lyon and James A. Bizell of the Department of Soil Technology, Cornell University, Ithaca, N. Y., was read by title.

Joseph S. Hepburn, A.M., M.S., Secretary of the Section, delivered an address upon "Recent Progress in the Chemistry of the Terpenes and Camphors," in which was reviewed the work of Wallach upon terpenes, camphors, cyclic ketones and their related compounds. Inversion of the terpene compounds and the occurrence of oxonium derivatives in this series were also discussed. The lecture was illustrated with charts and specimens of the terpenes, camphors and essential oils. A number of lantern slides were shown bearing upon the chemistry and technology of these compounds. The paper was discussed and referred for publication.

A vote of thanks was tendered the speaker, and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Electrical Section.—A meeting of the Section was held on Thursday evening, December 29, 1910, at 8 o'clock. In the absence of the Chairman the meeting was called to order by Dr. E. Goldsmith.

Sixty members and visitors present.

The minutes of the previous meeting were read and approved.

Mr. K. A. Albrecht, Electrical Engineer, of New York City, then presented an interesting communication on Arc Lamps with special reference to flame arcs. The speaker reviewed the subject of the development of the arc light from its experimental stages nearly a century ago and described many of the recent inventions and improvements. The subject was illustrated by models and lantern slides.

After a brief discussion the thanks of the meeting were extended to the speaker. Adjourned.

ALFRED RIGLING,
Acting Secretary.

Electrical Section.—A special meeting of the Section was held on Tuesday, January 3, 1911, at eight o'clock. Present, 175 members and visitors.

Dr. R. B. Owens, the Secretary of the Institute, introduced Mr. E. H. Flanders, Engineer of the Electric Storage Battery Company of Philadelphia, who presented a communication on a new battery for electric vehicles, known commercially as the iron-clad exide battery and recently placed on the market.

The speaker described the construction and action of the iron-clad battery and compared the performance characteristics with those of the exide and other forms of lead batteries and pointed out especially the advantages of the new form for intermittent and vehicle work. The subject was illustrated by lantern slides and complete batteries and parts were shown.

In the discussion which followed the paper Messrs. Forstall, Bartlett, Snyder, Spencer, Ford, Whitney, the chairman, and others participated.

Adjourned.

ALFRED RIGLING,
Acting Secretary.

Section of Physics and Chemistry.—The stated meeting of the Section was held in the Hall of the Institute on Thursday, January 5, 1911, at 8 P.M., with Mr. Alfred Rigling in the Chair. Thirty-eight members and visitors were present.

The minutes of the previous meeting were read and approved.

Professor William A. Pearson, Chemist to the Smith, Kline and French Company, delivered a lecture upon "The Preparation and Testing of Drugs," in which he discussed the manufacture and analytical control of "straight pharmaceuticals" or medicinal preparations made from plants, biological products and chemical compounds. The lecture was illustrated with lantern slides. The paper was discussed by Dr. A. W. Miller and others. On motion of Mr. Henry F. Colvin, a vote of thanks was tendered Professor Pearson.

On motion the meeting adjourned, after having referred the paper to the Committee on Publications.

JOSEPH S. HEPBURN,
Secretary.

Electrical Section.—A meeting of the Section was held on Thursday evening, January 12th, at eight o'clock,

Mr. Thomas Spencer in the Chair.

Present, fifty members and visitors.

The minutes of regular meeting of December 29, 1910, and of the Special Meeting of January 3, 1911, were approved.

The Chairman introduced Mr. G. S. Merrill, Assistant to the Chief Engineer of the National Electric Lamp Association, who read an interesting paper on "New Metallic Filament Lamps.' The physical properties of osmium, tungsten, molybdenum, tantalum, and other filament materials were given consideration. Filament testing and testing apparatus were fully described and numerous results of tests were shown. The subject was illustrated by lantern slides.

In the discussion which followed the paper, Mr. Hering, Dr. Owens, Mr. Greenfield, the Chairman, and others participated.

The thanks of the meeting were extended to the speaker and his paper was referred to the Committee on Publications.

Adjourned.

ALFRED RIGLING,
Acting Secretary.

MEMBERSHIP NOTES.

Elections to Membership.

RESIDENT.

MR. WILLIAM HEILPRIN, manufacturer, 1429 N. Twenty-first Street, Philadelphia.

Changes of Address.

MR. WILLIAM G. ROGERS, 1327 S. Wilton Street, Philadelphia.
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MR. JOHN G. FELTON, 57 First Ave., Gloversville, N. Y.

NECROLOGY.

MRS. L. S. BARNES, 2200 Pine Street, Philadelphia.

LIBRARY NOTES.

Purchases.

GILL, A. H.—Engine-Room Chemistry.
ZUR NEDDEN, D. F.—Engineering Workshops, Machines and Processes.
PULLEN, N. W. F.—Injectors.
GUNN, J.—The Practical Design of Motor Cars.
ENNIS, W. D.—Applied Thermodynamics for Engineers.
COLLINS, H. E.—Shaft Governors.
COLLINS, H. E.—Erecting Work.
COLLINS, H. E.—Shafting, Pulleys, Belting and Rope Transmission.
COLLINS, H. E.—Pipes and Piping.
COLLINS, H. E.—Boilers.
COLLINS, H. E.—Knocks and Kinks.
COLLINS, H. E.—Steam Turbines.
WOODWORTH, J. V.—Grinding and Lapping Tools, Processes and Fixtures.
WOODWORTH, J. V.—Gages and Gaging Systems.
ARRHENIUS, S.—Worlds in the Making.
CLARKE, J.—Physical Science in the Time of Nero.
LOGNE, C. H.—American Machinist Gear Book.
SINCLAIR, A.—Development of the Locomotive Engine.
Standard Handbook for Electrical Engineers, 1910.
HARRIS, E. G.—Compressed Air.
KENT, WM.—The Mechanical Engineers' Pocket-Book.
GOODRICH, C. L. and STANLEY, F. A.—Automatic Screw Machines and Their Tools.
WEST, P. C. H.—The Modern Manufacture of Portland Cement, vol. i.
JEPSON, G.—Cams and the Principles of Their Construction.
MEES, C. E. K.—The Photographs of Coloured Objects.
SOTHERN, J. W.—The Marine Steam Turbine.
PEIRCE, B. O.—Elements of the Theory of the Newtonian Potential Function.
PENDRED, V.—The Railway Locomotive.
STEINMETZ, C. P.—Engineering Mathematics.
DONALDSON, F.—Practical Shaft Sinking.
HECK, R. C. H.—Notes on Elementary Kinematics.
GOODRICH, C. L., and STANLEY, F. A.—Accurate Tool Work.
MAXWELL, W. H., and BROWN, J. T.—The Encyclopædia of Municipal and Sanitary Engineering.
PEDDLE, J. B.—The Construction of Graphical Charts.
SMITH, F. E.—A Hand-Book of General Instruction for Mechanics.

Gifts.

The art of Distillation: or a treatise of the choicest spagyrical preparations, experiments, and curiosities, performed by way of distillation, together with the description of the choicest furnaces and vessels used by ancient and modern chymists and the anatomy of gold and silver; with the

chiefest preparations and curiosities thereof; together with their vertues. In six books by John French, Dr. in physick. . . . London, 1667. (From Mr. Richard Waln Meirs.)

On the Nature of Things, nine books; written by Philipp Theophrastus of Hohenheim called Paracelsus: The titles of the nine bookes. Of the generations, growths, conservations, life, death, renewing, transmutations, separations, signatures of naturall things. London, 1650. [With this work is bound a copy of "A New Light of Alchymie," by the same author.] (From Mr. Richard Waln Meirs.)

The Hermetical Triumph: or, the victorius philosophical stone. A treatise more compleat and more intelligible than any extant, concerning the hermetical magistery. Translated from the French. To which is added the Ancient War of the knights, . . Translated from the German. London, no date. (From Mr. Richard Waln Meirs.)

Hermippus Redivivus: or, the sage's triumph over old age and the grave Wherein, a method is laid down for prolonging the life and vigour of man. Including, a commentary upon an antient inscription, in which this great secret is revealed; supported by numerous authorities. The second edition. London, 1749. (From Mr. Richard Waln Meirs.)

The magical writings of Thomas Vaughan (Eugenius Philalethes). A verbatim reprint of his first four treatises; anthroposophia, theomagica, anima magica, abscondita, magia adamica, and the true cœlum terræ by Arthur Edward Waite. London, 1888. (From Mr. Richard Waln Meirs.)

The works of the highly experienced and famous chymist, John Rudolph Glauber: containing, great variety of choice secrets in medicine and alchymy in the working of metallick mines, and the separation of metals: also, various cheap and easie ways of making salt-petre, and improving of barren land, and the fruits of the earth. Translated into English, and published for publick good by the labour, care, and charge, of Christopher Packe, Philo-chymico-medicus. London, 1689. (From Mr. Richard Waln Meirs.)

Cincinnati, Ohio, Commissioners of Waterworks. Eighth, ninth, tenth, eleventh and Final Report. Cincinnati, 1904 to 1909. (From the Commissioners.)

Wisconsin State Historical Society. Collections, vol. xix. Madison, 1910. (From the Society.)

New Zealand Mines Department. Papers and reports relating to Minerals and Mining. Wellington, 1910. (From the Department.)

Atlantic Deeper Waterways Association. Report of the proceedings of the Third Annual Convention held at Providence, 1910. Philadelphia, 1910. (From the Hon. J. Hampton Moore.)

American Society of Mechanical Engineers. Transactions, vol. xxxi, 1909. New York, 1910. (From the Society.)

Staffordshire Iron and Steel Institute. Proceedings, vol. xxv, 1909–1910. Stourbridge, 1910. (From the Institute.)

Tonindustrie Kalender 1911, three parts. Berlin, 1910. (From the Tonindustrie Zeitung.)

Liverpool Engineering Society. Transactions, vol. xxxi, 1909–1910. Liverpool, 1910. (From the Society.)

Chief Inspector of Mines of Ohio. Thirty-fifth Annual Report for 1909. Springfield, 1910. (From the Inspector.)

Philadelphia Bureau of Surveys. Report for 1909. Philadelphia, 1910. (From the Bureau.)

California State Mining Bureau. Bulletins No. 54–59 incl. Sacramento, 1909–1910. (From the University of California.)

Harvard University Catalogue for 1910–1911. Cambridge, 1910. (From the University.)

Ontario Department of Agriculture. Report of the Farmers' Institutes for 1909, Part I. Toronto, 1910. (From the Department.)

U. S. Navy Department—Bureau of Yards and Docks. Report of the Chief for 1910. Washington, 1910. (From the Department.)

U. S. Navy Department—Bureau of Construction and Repair. Report of the Chief for 1910. Washington, 1910. (From the Department.)

SNOW, WM. G.—Ventilation in its Relation to Health. Camden, 1910. (From Warren Webster & Company.)

U. S. Bureau of Education. Report of the Commissioner, vol. i. Washington, 1910. (From the Bureau.)

Massachusetts Institute of Technology. Catalogue, Dec., 1910. Boston, 1910. (From the Institute.)

Australia Bureau of Census and Statistics. Trade and Customs and Excise Revenue of the Commonwealth for 1909. Melbourne, 1910. (From the Bureau.)

Canada Minister of Public Works. Report for year ending March, 1910. Ottawa, 1910. (From the Dept. of Public Works.)

U. S. Department of Trade and Commerce. Annual Report of the Operations of the Light-House Board for year ending June 30, 1910. Washington, D. C., 1910. (From the Department.)

Canada, Bureau of Mines. Nineteenth Annual Report, part 1. Toronto, 1910. (From the Bureau.)

Burroughs Adding Machine Co. Book on "Cost Keeping Short Cuts." Detroit, 1910. (From the Company.)

Missouri Botanical Garden. Twenty-first Annual Report. St. Louis, 1910. (From the Garden.)

Vulcanite Portland Cement Co. Pamphlets on "Concrete in the Country" and "Concrete Surface Finishes." Philadelphia, 1910. (From the Company.)

Maine, Bureau of Industrial and Labor Statistics. Report. Augusta, 1910. (From the Bureau.)

American Railway Master Mechanics' Association. Proceedings, vol. xliii. Chicago, 1910. (From the Association.)

U. S. Library of Congress. Report of the Librarian for year ending June, 1910. Washington, D. C., 1910. (From the Library.)

New York State Museum. Bulletin No. 45 "Geology of the Thousand Islands Region." Albany, 1910. (From the Museum.)

Pennsylvania Railroad Company. Test Department. Bulletin No. 5. Tests of an E2A Locomotive, 1910. (From the Pennsylvania R. R. Co.)

Connecticut Bureau of Vital Statistics. Sixty-second Registration Report, 1909. Hartford, 1910. (From the Bureau.)

Ontario Department of Agriculture. Report of the Women's Institutes, Part I. Toronto, 1910. (From the Department.)

Australia Bureau of Census and Statistics. Shipping and Oversea Migration for 1909. Melbourne, n. d. (From the Bureau.)

Astronomical and Astrophysical Society of America. Publications, vol. i. Ann Arbor, 1910. (From the Society.)

Institution of Civil Engineers. Minutes of the Proceedings, vol. clxxxii. London, 1910. (From the Institution.)

U. S. Navy Department. Navy Yearbook, 1910. Washington, D. C., 1910. (From the Department.)

U. S. Navy Department. Report of the Secretary of the Navy. Washington, 1910. (From the Department.)

U. S. Navy Department. Report of the Surgeon-General. Washington, 1910. (From the Department.)

Navy Department. Report of the Paymaster-General. Washington, D. C., 1910. (From the Department.)

BOOK NOTICES.

L'ANNUAIRE DU BUREAU DES LONGITUDES POUR L'AN 1911 AVEC DES NOTICES SCIENTIFIQUES. Publié par Le Bureau des Longitudes. 750 pages, 3¾″ x 6″. Paper, 1 fr., 50 net; by mail, 1 fr. .85. Gauthier-Villars, Paris, 1910.

As the title indicates, this work is the standard French almanac containing official data of interest to mariners and astronomers and much other information of scientific value. The usual appendix at the end of the volume this year contains an account by M. H. Poincaré of the Conference of the International Geodetic Association and a contribution by M. G. Bigourdan on the Eclipse of the Sun of April 17, 1912.

PENROSE'S PICTORIAL ANNUAL. The Process Year-Book, edited by William Gamble, 1910–11, vol. 16. London, A. W. Penrose & Co., Ltd. Price, in cloth, 7 shillings. American agents, Messrs. Tennant & Ward, New York.

The present volume of this well-known annual contains one hundred and ninety-two pages of text in which are included sixty illustrated articles by eminent authorities dealing in an interesting manner with important matters of theory and practice in process work, printing, photography, and allied trades.

The illustrations in the present volume are more numerous and more beautiful than those in previous issues and show the remarkable improvements and developments which have been made during the year in illustrative methods.

Thirty-five full-page specimens of one, two, three, and four-color plates, several examples of lithographic offset printing in from one to ten colors and many smaller half-tones and engravings serve to make the volume of considerable interest even to those who are in no way connected with the reproductive arts.

PUBLICATIONS RECEIVED.

U. S. Bureau of Mines. Bulletin No. 2. North Dakota Lignite as a fuel for power-plant boilers. By D. T. Randall and Henry Kreisinger. 42 pages, illustrations, plates, 8vo. Washington, Government, 1910.

The End of Darwinism. Not change but persistence is characteristic of life. Every change is essentially a persistence; only what persists can change. An essay by Alfred P. Schultz, M.D., author of "Race or Mongrel," "The Children of Everybody," etc. Monticello, New York, author. Price, in paper, 50 cents.

U. S. Department of Commerce and Labor, Bureau of the Census. Bulletin 109. Thirteenth census of the United States. Population by States and Territories. 7 pages, Q. Washington, Government, 1910.

Qualitative Chemical Analysis from the stand-point of solubilities, ionization and mass action. By J. I. D. Hinds, Ph.D., LL.D., Professor of Chemistry, University of Nashville and Peabody College for Teachers, Nashville, Tenn. 265 pages, 8vo. Easton, Chemical Publishing Co., 1910. Price, in cloth, $2.00.

Canada Department of Mines, Mines Branch. The production of cement, lime, clay products, stone, and other structural materials in Canada during the calendar year 1909. By John McLeish, B. A. 47 pages. Ottawa, Government, 1910.

The Department of Mines of Canada, its organization and its work. By Alfred W. G. Wilson. 12 pages, 8vo. Reprinted from Economic Geology, vol. v, No. 7, October–November, 1910.

U. S. Department of Agriculture, Bureau of Soils. Bulletin No. 74. Chemical nature of soil organic matter. By Oswald Schreiner and Edmund C. Shorey. 48 pages, plate, 8vo. Washington, Government Printing Office, 1910.

U. S. Bureau of Mines, Bulletin No. 5. Washing and coking tests of coal at the fuel-testing plant, Denver, Colo., July 1, 1908, to June 30, 1909. By A. W. Belden, G. R. Delamater, J. W. Groves and K. M. Way. 62 pages, 8vo. Washington, Government, 1910.

U. S. Commissioner of Education. Report for the year ended June 30, 1910, vol. i. 662 pages, 8vo. Washington, Government, 1910.

Leçons sur l'Electricite professées a l'Institut Electrotechnique Montefiore par Eric Girard. Eighth edition, 2 vols., illustrations, 8vo. Paris, Gauthier-Villars, 1910. Price, in paper, 24 francs.

An Introduction to Thermodynamics for Engineering Students. By John Mills, Professor of Physics and Electrical Engineering, Colorado College. 136 pages, illustrations, plates, 8vo. Boston, Ginn & Co., n. d.

Relation between Uranium and Radium. V. F. SODDY. (*Phil. Mag.*, xx, 340.)—Previous experiments showed that the rate of growth of Ra, in some old solutions of Ur was according to the square of the time and from this the existence of a long-lived intermediate parent (ionium) of Ra was deduced. Measurements made later have not confirmed the rate of growth, and the estimates are withdrawn; and the results afford data for the calculation of the minimum period of the supposed product. This minimum period is deduced to be 35,000 years.

The Electric Furnace. G. ARNOU. (*Rev. Met.*, vii, 1054.)—The analysis of several steels prepared in the electric furnace are given, ranging from one containing carbon 0.08 per cent., manganese 0.16, sulphur 0.012, phosphorus 0.008, and silicon 0.10, to one containing carbon 0.87 per cent., manganese 0.31, sulphur 0.01, phosphorus 0.005, and silicon 0.37. Attention is called to the low manganese content, to the absence of gases and of oxide, and to the remarkable homogeneity of the products, which results in a great malleability when cold and a very great resistance to shock. Details are given of the mechanical tests such as tension, deflection on bending, and resistance to the shock of a falling weight, which show the great superiority of electric steel. With an equal content of carbon, tungsten, manganese, etc., the initial magnetization was five or six per cent. greater than in ordinary magnets, while the permanent magnetism was about the same.

Heat-Treating High-Speed Tools. C. P. BERG. (*Amer. Mach.*, xxxiii, 45, 872.)—The statements as to the tempering of high-speed tools generally cover such a wide range of temperatures that the minimum would leave the tool far below its best hardening heat, while the maximum, for several brands of steel, would completely ruin the tool for work, by burning. This article establishes the relation that exists between the hardening temperature and the life of high-speed tools, and establishes a guide for the rapidity of heating while heat-treating, by using heat absorption tests. It also determines the degree of temperature that gives different steels the maximum cutting efficiency, the hardness produced and the results obtained from severe physical tests. This is a valuable article to those interested.

Wood Distillation.—A report made to the Census Bureau states that there was consumed in the United States during the calendar year 1909 in the industry of wood distillation, 1,265,000 cords of wood, as against 978,000 cords in 1908 and 1,282,000 cords in 1907. The average cost per cord reported for the 1909 consumption was $3.21, which was an increase of 23 cents, or 8 per cent., over that reported for 1908, and of 6 cents, or 2 per cent., over that for 1907. While a substantial increase is noted in that branch of the industry using yellow pine, fir, and other softwoods as material, the revival of activity was more marked in hardwood distillation, due undoubtedly to the material advance in the average value per gallon of wood alcohol over the two preceding years.

HARDWOOD DISTILLATION.

The distillation of hardwoods was reported from 14 States during 1909, while in 1908 and 1907 it was pursued in only 8 States. Michigan, Pennsylvania, and New York, however, continue to be the centres of activity in this branch of the industry. These three States consumed 84 per cent. of the total quantity of hardwoods reported as used during 1909, and contributed, of the total output of each of the three leading products, charcoal, wood alcohol, and gray acetate, 82 per cent., 93 per cent., and 92 per cent., respectively.

While the average value per unit has varied little for most of the products of hardwood distillation during the past three or four years, for alcohol it has fluctuated over a wide range, following the passage of the so-called denatured alcohol law, which became effective January 1, 1907. The average value per gallon reported for crude alcohol manufactured during the calendar year 1906 was 34 cents. In 1907 it dropped to an average of 15 cents, increased to 17 cents during 1908, and reached an average of 24 cents in 1909.

SOFTWOOD DISTILLATION.

The leading product in point of value in softwood distillation during 1909 was turpentine, and Georgia, Florida, and Alabama, ranking among themselves in the order named, contributed together 68 per cent. of the total output of this commodity. While the total number of active establishments was substantially the same in each of the three years, there has been considerable change in the number in operation in the several States. This is due largely to the fact that various methods of softwood distillation have been tried during recent years, some of which have not proven satisfactory, the industry as a whole being still to some extent in an experimental

stage. The use of sawdust and other mill waste as material in 1909 was substantially greater than in any preceding year and the indications are that the industry will develop largely in future in the direction of utilizing this class of material.

THE COMPARATIVE SUMMARY.

Hardwood Distillation.	1909	1908	1907
Number of plants	116	101	100
Material:			
Beech, birch, maple, etc., cords	1,150,000	879,000	1,220,000
Cost	$3,818,000	$2,711,000	$3,825,000
Products:			
Total value	$7,642,000	$5,408,000	$7,661,000
Charcoal, bushels	53,075,000	37,287,000	50,772,000
Value	$3,299,000	$2,645,000	$3,838,000
Crude alcohol, gallons	8,468,000	6,286,000	7,742,000
Value	$2,082,000	$1,084,000	$1,153,000
Gray acetate, pounds	148,769,000	108,099,000	133,375,000
Value	$2,303,000	$1,637,000	$2,566,000
Brown acetate, pounds	2,157,000	1,580,000	8 153,000
Value	$22,000	$13,000	$94,000
Iron acetate, gallons	303,000	263,000	.....
Value	$28,000	$25,000	.....
Oils, gallons	38,000	58,000	383,000
Value	$3,000	$4,000	$9,000
All other products, value	$5,000	.....	.....

Softwood Distillation.	1909	1908	1907
Number of plants	31	30	31
Material:			
Total cost	$242,000	$207,000	$211,000
Longleaf pine, cords	100,000	91,000	61,000
Cost	$234,000	$202,000	$211,000
All other, including mill waste, cords	16,000	8,000	1,000
Cost	$8,000	$6,000	$200
Products:			
Total value	$687,000	$491,000	$535,000
Turpentine, gallons	683,000	506,000	655,000
Value	$243,000	$166,000	$305,000
Charcoal, bushels	2,403,000	1,996,000	1,158,000
Value	$210,000	$187,000	$102,000
Oil, gallons	323,000	305,000	392,000
Value	$70,000	$56,000	$69,000
Tar, gallons	1,365,000	967,000	761,000
Value	$105,000	$81,000	$58,000
All other products, value	$59,000	$800	.....

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